PONTIFICIAE ACADEMIAE SCIENTIARVM SCRIPTA VARIA

57

STUDY WEEK

ON:

ENERGY FOR SURVIVAL AND DEVELOPMENT

June 11-14, 1984

EDITED BY

CARLOS CHAGAS and UMBERTO COLOMBO

PONTIFICIA
ACADEMIA
SCIENTIARVM

EX AEDIBVS ACADEMICIS IN CIVITATE VATICANA

MCMLXXXVI

PONTIFICIAE ACADEMIAE SCIENTIARVM SCRIPTA VARIA

57

STUDY WEEK

ON:

ENERGY FOR SURVIVAL AND DEVELOPMENT

June 11-14, 1984

EDITED BY

CARLOS CHAGAS and UMBERTO COLOMBO

PONTIFICIA
ACADEMIA
SCIENTIARVM

EX AEDIBVS ACADEMICIS IN CIVITATE VATICANA

MCMLXXXVI

INDEX

SCIENTIFIC PAPERS

FOREWORD

I am most grateful to all of you for having accepted the invitation of the Pontifical Academy of Sciences, and for your willingness to give up some of your time to discuss this important topic. I am particularly thankful to our friend Umberto Colombo and to ENEA, the Italian Nuclear and Alternative Energy Sources Commission, for having helped us to organize this meeting.

I am impressed by the scientific and professional competence of the participants; by the fact that most, if not all, the papers to be delivered are already available in written form, and by the breadth of our programme, which will allow us to analyse in great depth the problem of energy and the developing countries. Thanks to the variety of experience represented at the meeting, I am confident that we shall come to extremely interesting conclusions and recommendations.

I regret that we were unable to invite a greater number of experts: as many of you know, it is our habit to limit the participants at our Study Weeks to a small number because we have found that this is the best way to obtain a fruitful exchange of ideas amongst those present. I regret, however, that the Chairman of the Presidium of the Chinese Academy of Sciences, Prof. Yan Jici, who had planned to be with us, was obliged to cancel his attendance at the last moment.

Four years ago, brilliantly organized hy one of our Pontifical Academicians, Professor André Blanc-Lapierre, a Study Week was held on "Mankind and Energy: Needs, Resources, Hopes". It was during this Study Week, dedicated to discuss the wider aspects of the energy problem, that we decided that, as was most especially illustrated in the reports of Mr. Konan, Mr. Sanchez-Sierra, Mr. Pasztor and Mrs. Parikh, we ought to have a meeting specifically dedicated to the scientific problem of the role of energy in the less developed countries.

The problem in 1980 was already very grave. It has worsened dramatically with the increasing level of Third World indebtedness (today over $ 600 billion) and the consequent drain of resources for debt service.

Total reliance on the workings of market forces is no solution. The very high cost of energy — especially of oil — is denying less developed countries the resources vital for their development. Yet we cannot ignore the market economy, however cold its logic seems to be, as it can at least provide a valuable tool for the comparison of the relative benefits of each potential alternative solution.

"Energy for Survival and Development" is the title of our Study Week. We must therefore concentrate our attention on the problems and perspectives of developing countries. But the problem is wider than that — it embraces the whole of humanity. The gap between rich and poor cannot be allowed to continue indefinitely. Mankind would pay a high price for such negligence.

The Holy Father is following our activity with particular attention and enthusiastically approved the idea of holding this Study Week. I am sorry to inform you that we shall not have the honour of meeting His Holiness on this occasion as he is at present visiting Switzerland.

He has, however, charged me to present his greetings to you all, and to tell you that he is looking forward with great expectation to the conclusions and recommendations of our Conference. I urge you, in the tradition of the Pontifical Academy of Sciences, to feel free to express your ideas. You are not here representing your countries, nor your organizations, but rather as individuals who have devoted their lives to the progress of science and technology. You are here to give us the benefit of your wisdom and collective knowledge.

We are living in a world rapidly becoming dominated by information. Interdependence is the characteristic of our times. Our joint efforts can therefore validly attempt to find ways of bridging, and with God's help, eliminating the injustice of the division of our world into two so different and contrasting halves.

For this reason we at the Pontifical Academy have invited experts from the Third World, and also from OECD countries and from the USSR. Moreover it is a source of great satisfaction to us that eminent representatives of organisations such as the International Energy Agency, the International Atomic Energy Agency, the World Bank, the European Community, and the United Nations are present here today.

The Pontifical Academy of Sciences is planning a follow-up to this Study Week. Our work will be a contribution to a problem of great strategic importance. The problem must be faced with profound confidence in the ability of science and technology inspired by the highest ethical values to further our progress toward a more harmonious society.

As has been done on otber occasions, the proceedings will contain not only the papers, but also a synthesis of our discussions. Professor Colombo has assumed the responsibility for coordinating this effort.

On behalf of the Academy I wish to thank Drs. Paolo Baronti and Andrea Aparo for having agreed to serve as rapporteurs during this Study Week.

And my special thanks to Father Enrico di Rovasenda, the extremely able Director of our Chancellery and to Dr. Vanni Garofoli, Assistant to the Chairman of ENEA, for their substantial contribution to the organization of our week.

I would like also to express my gratitude to Mrs. Michelle Porcelli Studer and Mr. Silvio Devoto from the Pontifical Academy of Sciences and to Ms. Françoise Azemar and Ms. Anna Maria Vita from ENEA, without whose tireless contribution we would not have been able to hold this meeting.

Carlos Chagas
President of the Pontifical Academy of Sciences

LIST OF PARTICIPANTS

ADNAN AL-HOMOUD, Kuwait Institute of Scientific Research, P.O. Box 24885, Safat, Kuwait.

ARNALDO M. ANGELINI, Honorary Chairman ENEL, Italian National Electric Power Authority, Via G.B. Martini 3, 00198 Rome, Italy.

BJORN BARTH, International Energy Agency - 2, Rue André Pascal, F-75775 Paris Cedex 16, France.

OLIVIERO BERNARDINI, CESEN - Centro Studi Energia « Renzo Tasselli », Via Serra 16, 16122 Genova, Italy.

ANDRÉ BLANC-LAPIERRE, Pontifical Academician, Université Paris IX, Résidence Voltaire, 92290 Châtenay-Malabry, France.

ALFRED BOETTCHER, Koordinator für Bilaterale Zusammenarbeit des Bundesministeriums für Forschung und Technologie, Kernforschungsanlage Jülich, GmbH, Jülich, F.R. of Germany.

JANE CARTER, International Association Energy Economists, 27 Gilkes Crescent, Dulwich Village, London, SE21 7BP - England.

CARLOS CHAGAS, President of the Pontifical Academy of Sciences, Vatican City.

NAZLI CHOUCRI, Associate Director, Technology Adaptation Program and Department of Political Science M.I.T., E53-493 Cambridge, Massachusetts 02139 U.S.A.

UMBERTO COLOMBO, Chairman ENEA, Italian Commission for Nuclear and Alternative Energy Sources, Viale Regina Margherita 125, 00198 Rome, Italy.

Jean Couture, Président, Institut Français de l'Energie - 3, Rue Henri Heine - 75016 Paris, France.

K.S. Demirchian, Corresponding Member, USSR Academy of Science, Institute of High Temperature, Moscow, USSR.

Pierre Desprairies, President, Institut Français du Pétrole, 4, Avenue de Bois Préau - 92506 Rueil Malmaison Cedex, France.

Jean-Loup Dherse, Vice President, The World Bank, International Bank for Reconstruction and Development, International Development Association, Washington, D.C. 20433 U.S.A.

Andrea Di Vecchia, Department for Cooperation to Development, Ministry of Foreign Affairs, Farnesina, 00194 Rome, Italy.

Richard J. Eden, University of Cambridge, Department of Physics, Madingley Road, Cambridge CB3 OHE, England.

Ugo Farinelli, ENEA, Director, Department for Alternative Energy Sources and Energy Conservation, Viale Regina Margherita 125, 00198 Rome, Italy.

Maurice Foley, European Communities, Directorate - General VIII Development, Rue de la Loi, 200, 1049 Brussels, Belgium.

Jean Romain Frisch, Assistant to the General Manager, Long Term Energy Studies, Electricité de France, 32, Rue de Monçeau, 75008 Paris, France.

José Goldemberg, President, CESP Eletropaulo, Al. Ministro Rocha Azevedo 25, Sao Paulo, Brasìl.

Fatima Gonzales Ortega, Energy Ministry, Antiguo Edificio IBM de Montoya, Managua, Nicaragua.

Munir Ahmad Khan, Chairman, Pakistan Atomic Energy Commission (PAEC), P.O. Box 1114, Islamabad, Pakistan.

LAMBERT KONAN, Directeur Général, Société Energie Electrique, Post Box 1345, Abidjian, Ivory Coast.

HANS H. LANDSBERG, Resources for the Future, 1755 Massachusetts, Avenue N.W., Washington D.C., 20036 U.S.A.

HANS JUERGEN LAUE, Director, Division of Nuclear Power, International Energy Agency, Vienna, Austria.

BOUBAKER LEMKECHER, Advisor to the Minister of National Economy, La Kasbah, Tunis, Tunisia.

WA KALENGA MALU, Pontifical Academician, Director, Kinshasa Regional Center for Nuclear Studies, University of Zaire in Kinshasa, B.P. 184, Kinshasa XI, Zaire.

GIOVANNI BATTISTA MARINI-BETTÒLO, Pontifical Academician, Università di Roma La Sapienza and Istituto di Chimica, Università Cattolica del S. Cuore, Rome, Italy.

KAZUAKI MATSUI, Manager, Research and Development Division, Institute of Applied Energy, Toshin Bldg, 1-13 Shinbashi 1-Chome, Minatu-Ku, Tokyo, Japan.

MOISE MENSAH, Vice-President, International Fund for Agricultural Development, Via del Serafico 107, 00142 Rome, Italy.

M. GOVIND KUMAR MENON, Pontifical Academician, Member Planning Commission Government of India, Yojana Bhavan, Parliament Street, New Delhi 110001, India.

GIAMPIETRO PUPPI, Pontifical Academician, Istituto di Fisica della Università di Bologna, Via Irnerio 46, Bologna, Italy.

KIRK R. SMITH, Energy Program Leader, Resource Systems Institute, East West Center, 1777 East West Road, Honolulu, Hawaii 96848 U.S.A.

CARLOS E. SUAREZ, Institute of Energetic Economy (IDEE) c.c. 138 8400 Bariloche, Rio Negro, Argentina.

M.W. THRING, Queen Mary College, Department of Mechanical Engineering, University of London, Mile End Road, London, England E1 4NS.

HAMAR ZEGHBIB, Vice-Director, Ministry of Energy, Alger, Algeria.

Rapporteurs:

Dr. ANDREA APARO, ENEA, Rome, Italy.

Dr. PAOLO BARONTI, ENEA, Rome, Italy.

Head of the Secretariat:

Dr. VANNI GAROFOLI, ENEA, Rome, Italy.

Participants in the Study Week.

SCIENTIFIC PAPERS

INTRODUCTION

We have just heard the opening address of the distinguished President of the Pontifical Academy of Sciences, Prof. Carlos Chagas, who has told us about the global problems to which the Academy is making its contribution with humility and yet with its great prestige. We are grateful that the problem of energy, related to the needs of the developing countries, has been selected by the Academy as a high priority subject. We trust that this Study Week will provide indications for future actions of the type just mentioned by Prof. Chagas.

The poverty in which over one-half of mankind lives and the persisting gap between the rich and the poor are not only a human tragedy, they are two of the greatest problems of our time.

To believe that rich and poor countries can forever be neatly separated is an illusion. Affluent countries or their governments, basing their prospects for the future on their capabilities of further expansion of wealth and consumption, without taking into account the conditions of the majority of the inhabitants of the world, are not only morally reprehensible: they are making a historical mistake. The survival of the world, and of industrial countries in particular, is conditioned by the problem of development.

The solution of this problem is in turn dependent upon cooperation between the rich and the poor, on growing interdependence and interaction between the two balves of the world, and, most importantly, on general recognition of this truth.

The gap between rich and poor countries has its parallel locally in the distance between small élites living "in the 20th century", with products and consumption typical of technologically advanced industrial societies, and the sea of poverty surrounding them. In this situation the poor majority have under their eyes the model of what is possible with development, yet cannot be reached in practice — and this makes decoupling of developed and developing countries even more of an illusion.

Those who have been convened here by the Pontifical Academy of Sciences have different origins, backgrounds and beliefs. What they have in common is not merely knowledge and experience in energy problems, it is above all a shared genuine interest and moral commitment to the cause of development.

Energy is an important part of the problem, because it is essential to survival and development. More energy is needed for agriculture if the production of food is to cope with persisting malnutrition, escalating to famine and starvation, and is to keep abreast of the increase in population; irrigation, fertilizers, pesticides, a minimum of mechanization, all require substantial quantities of energy. To conserve food when it is harvested, to process it and to cook it, further energy is required. Energy, even if in small quantities, is essential for health, at the right places and times: refrigeration of medicines and vaccines, and purification of drinking water are but two vital examples. Small quantities of energy are sufficient to ensure communications, basic to education, social development and organizations, and to community life, but even this energy is often not available where and when it is needed.

Transportation of people and goods requires large quantities of energy, but it is an essential factor in making use of existing resources, for operating a transition from the primitive society of self-sufficiency and isolation to a society based on exchange and cooperation. And of course the availability of energy is the prerequisite for any step towards industrialization.

Along with almost everything else, energy has always been scarce in most of the less-developed countries; it has become more so in many countries since the oil crises of the 1970s. The burdensome import budgets of the poor countries and their chronic shortage of foreign exchange have forced them to resort to heavy borrowing abroad to offset the impact of the multiple increase in the oil price. The consequences for their financial viability can only be described as critical, while this temporary alleviation in import availability must be followed by a drastic impact on the development and standard of living of many of these countries, as international lending declines or dries up. Economic setbacks suffered by industrialized countries as a result of these same events will then seem minor in comparison.

Lack of energy not only hampers development directly, it also works through a number of indirect channels. For example, use of firewood in place of oil has created a major threat of deforestation and even desertification in many countries. Burning animal and vegetal wastes competes with their use as fertilizers. Scarce energy has often to be replaced by increased labor, and as a consequence less working power is available for industry and services.

The thinning of forests, as a consequence of overexploitation, means longer chores to collect the wood necessary to a family, and more manpower is then lost to productive activities. Lack of energy, or difficulties in its availability, and the resultant poor quality of life accelerate the process of excessive urbanization, for it is easier and less expensive to provide energy in an urban agglomeration than in remote locations in the countryside.

Making more energy available to less developed countries is therefore an objective which is widely recognized as a high priority both by the developing countries themselves and by those organizations at the national and international level that support development projects. A significant proportion of the money devoted to this support is spent on energy.

Notwithstanding this emphasis, it is not at all clear whether these programmes have succeeded in general terms (and not only in some specific local achievements). Nothing is apparent to be compared to the success of the "green revolution", which from its beginning in the sixties has so greatly improved the production of staple food in many of the less developed countries. Obviously no "energy revolution" analogous to the green revolution has taken place, and success, where present, would be difficult to evaluate, except on a local scale. Why is this so? The answer is neither simple nor unique, hut looking for it may help us to understand the situation better and to identify possible remedies. I shall try briefly to illustrate six points which seem to me to have a certain relevance.

First of all, not much is known of how much energy is produced and consumed in the less developed countries. The main reason for this gap in our knowledge is that a large part of this energy — often more than one-half — is not commercial and therefore generally escapes statistics. Shifts in the use of firewood or dung are just as important as those in oil or gas, but little information on this can be found in published official figures. This accounts for much of the absence of reliable and detailed evaluation of the energy situation in different countries and of any improvement as a result of development programmes.

Second, the lack of energy is only one aspect, even if an important one, of poverty. The role of energy has been stressed and emphasized by the sudden steep increase in prices, which even rich countries had difficulties in coping with. The situation to be faced is one of rising energy prices; although much can be done to alleviate the consequences, no solution offering energy costs lower than those of 1973 is in prospect. The way out of the crisis is uphill, and the best one can hope for, at least during a long period of adjustment, is to prevent further impoverishment rather than to increase wealth.

Third, the problem is not only technical or economic, or cultural or political, but all of these together. Technologies to use the different energy sources are available; they can, and will, be improved in terms of costs, reliability and flexibility. They have to be tried and tested under differing conditions, to be selected according to local needs, situations and opportunities. The main obstacles to the diffusion of most energy options are likely to be of a non-technical nature. Economics of course plays an all-important role: it makes little sense to diffuse technologies that are more expensive than alternative options. However, purely economic considerations may obscure the fact that the social value of energy can be much higher in some cases than its market value. For example, considerations I mentioned earlier about energy for health or education, or the negative impacts of deforestation and urbanization, indicate that the social value of energy varies very much according to where and when it is made available, apart from purely commercial considerations. Similarly, rather than merely current operating costs, availability of convertible currency or of foreign credit often determines the choice of solutions based on imports or large initial investment. High interest rates make this situation even worse. Cultural and social conditions sometimes constitute opportunities, but more often obstacles to cost-efficient energy choices. Lack of education, of technical skills, of infrastructures, are often in the way of technologies that are cheaper but require home maintenance or are difficult to operate. Traditional ways of living, eating, cooking food, cultivating, etc., have to be taken into account in the analyses of energy use. It is generally more difficult to change even slightly these traditions than to introduce sophisticated technologies that do not interfere with them. Political considerations often weigh heavily in shaping energy choices. Strategic importance of fuels, competition of powers in certain areas, difficult relationships between neighbours, image values of certain initiatives are just a few examples of conditioning political elements which have to be taken realistically into account.

Fourth, there is certainly no unique solution to the energy problems of developing, and for that matter, of developed countries. Developing countries are a constellation with widely different conditions and characteristics; they differ among each other much more than industrialized countries do, and more than industrial countries differ from some of the developing countries. They differ not only in quantitative terms (such as income) but also qualitatively.

Fifth, energy programmes in developing countries have often been biased by the particular interest or viewpoints of those engaged in making decisions. For instance, an industrial country providing support to the development of another country will understandably be tempted to use this intervention to promote the penetration of its national industry in a potential market. What that industry will try to sell will be dictated by its own interest rather than the developing country's priorities.

Finally, the time scale of initiatives in LDCs has often been either too short or too long. The poorest countries are too hard pressed by survival problems to afford really to think ahead. At the other extreme, in rich countries concerned groups frequently put forward development models for LDCs that try to avoid errors and polarizations present in the life patterns of the industrialized world, and that may offer a better quality of life with lower consumption of energy and raw materials. The ideas behind these models are generally sound: what is often lacking is the identification of pathways that lead from here to there and are compatible with real conditions and constraints. Medium-term programmes are scarce; in addition, they require a continuous and assured commitment over many years, generally impossible to obtain in the context of national or international budgets.

If these are the difficulties met in energy programmes for developing countries, what can be done to overcome them?

Indications in this direction are precisely what we should hope will come out of this meeting, together with a better assessment of the situation. Without anticipating what recommendations may result from our discussions, there are a few general points that are worth mentioning in these introductory remarks.

First of all, we should refute the widespread misconception that there is no room for energy conservation in LDCs. The fact that so much less energy is consumed there than in the rest of the world does not imply in any way that this energy is consumed efficiently. On the contrary, one often finds out that there is relatively more wastage of energy there than elsewhere. For instance, open fires or primitive stoves have efficiencies lower than 25% in using the heat from burning wood or wastes. The doubling of this efficiency, easily attainable even with very simple stoves, would already constitute a formidable contribution to the conservation of scarce resources.

But energy conservation could go much further than that. For instance, since we have mentioned the success of the green revolution, one may well question whether the varieties of crops and agronomic practices developed in that context, when energy was much cheaper, should not be reconsidered. Reorientation of genetic research to the new goals, application of advanced biotechnologies, in addition to improved agronomic techniques, could supply new solutions, more adapted in terms of energy requirements to the new situation.

Similar considerations could be applied to the new emerging industries in developing countries: new technologies and often older ones could permit substantially lower energy requirements and a better adaptation to local conditions.

Secondly, attractive as new energy sources may appear, the most important contributions in the short and medium term could come from the old sources and in particular from hydrocarbons, most specifically if they are produced by the LDCs themselves. Although present geological analyses suggest that it is unlikely that very large oil or gas deposits are to be found in these countries, the same data indicate that in many of the developing countries there should be enough undiscovered hydrocarbon resources to meet local needs for a long time, although not in a quantity sufficient to make export attractive. Exploration activities in LDCs have not appreciably accelerated in the last ten years, notwithstanding the incentives inherent in the boost of oil prices. Drilling has increased only in those countries that already produced oil, and has remained at a negligible level in the others. Multinational companies having the technologies and capital needed for exploring such resources and later exploiting them are not interested due to the limited economic returns, the financial weakness of the countries, their lack of reliable long-term commitments. International organizations, and in particular the World Bank, have promoted exploration programmes for oil and gas by compiling data, providing technical assistance and expert advice, assessing past discoveries and giving direct help in later phases of oil development. This stimulation to local governments or companies, although certainly useful, may not prove adequate to the dimension of the problem. Inventiveness and ingenuity should be exercised to identify new approaches at the international level to encourage exploration and exploitation of relatively small oil resources in LDCs for local utilization without undue reliance on market forces.

The exploration of natural gas resources presents problems similar to, and often interconnected with those of oil exploration; their exploitation, however, has different aspects. The relatively greater difficulties in transporting gas make it necessary to develop gas utilization at the same pace as gas production. If these difficulties are overcome, the prospects for natural gas in LDCs are even more interesting than those for oil. A recent re-evaluation by the World Bank has indicated a potential increase by a factor of four of natural gas production in developing countries over a period of 15 years.

Where coal is present locally, its use will be substantially cheaper than that of imported oil in generating electricity and for a number of industrial uses. Large increases in its production are predicted in the next 10 years, but especially by two of the major producers (China and India). A number of difficulties remain on the way to greater exploitation of coal reserves: the need for large initial investments, with long payback times; the problems in setting up the necessary infrastructures, particularly for coal transportation to the main users; the limited expertise existing in LDCs on coal production and utilization.

Low-grade coals, such as peat and lignite, should also be considered for local use. Where substantial quantities of such fuels are present in conditions of easy access, their use for electricity production (provided it makes sense to have the power station on the site), and to some extent also for household consumption, may well relieve pressure on imported fuel or scarce firewood.

If coal is not present locally, its import may prove economically attractive as compared to oil imports; however, the difficulties mentioned above, and the problems to be overcome for converting power plants from oil to coal burning discourage many developing countries from such a shift, particularly in times of uncertain forecasting of the relative market prices of the two fuels.

Nuclear energy meets with a number of formidable difficulties for exploitation in developing countries. The size of the interconnected electrical grid is often not big enough to allow the insertion of such large units as are standard today in industrial countries. The technological background needed for operation, maintenance, safety assessment, handling of radioactive wastes, etc., is present only in a few of the developing countries. Anxiety concerning possible proliferation of nuclear weapons (sometimes well justified, at other times politically perhaps exaggerated) limits the transfer of technologies and of strategic materials; high investment costs and long lead times are required. However, in particular situations, where intensive urbanization is coupled with electricity-intensive industries, nuclear energy might provide electricity at the lowest cost. The development of standard nuclear power stations of a size much smaller than the now prevailing 1000-1200 MW, and more easy to maintain and operate, together with extended programmes of technical training, could help in making this complex technology accessible to more countries. Nor should it be overlooked that the know-how acquired in such programmes could help in improving the country's general technological and managerial expertise, with positive fall-out in other sectors of the economy.

Renewable energies have long played a major role in developing countries, especially as far as firewood and agricultural wastes are concerned. An improvement in the use of these traditional fuels is possible and important, but past experience has shown that it is not easy to achieve. Difficulties in diffusion and limits due to local conditions, habits and traditions are more important than any technical consideration.

New renewable energies may acquire increasing importance for LDCs, provided they are applied in the appropriate context. It is particularly important to identify opportunities and obstacles. The production of hot water or hot air by solar collectors can be economically attractive today, provided low-cost systems are available (in most cases they should be manufactured locally), and if the way they are utilized allows use of most of the solar energy collected. This may include not only domestic and commercial, but also agricultural and industrial uses.

Photovoltaic solar energy is still very expensive as compared with traditional sources. Its costs are rapidly decreasing, and the prospects for its widespread use for the substitution of diesel generators in isolated villages are getting closer. However, photovoltaics can already provide a qualitatively important, even if quantitatively limited contribution by bringing electricity to small communities that would otherwise remain without it.

Wind energy can provide the most economical solution for water pumping in many places; it is also close to the economic break-even point with oil for the production of electricity, not only in isolated locations but also within the grid when adequate average wind velocities can be found. Sufficient information on wind characteristics in LDCs is often not available.

Geothermal energy is present in a few countries (like the Philippines) with characteristics that allow production of electricity economically. Geothermal electricity production in LDCs is thus expected to increase in the next years by a factor of five, from the present 700 MW. In other countries, where geothermal hot water rather than steam is found at reasonable depths, utilization for space heating greenhouses or industry is possible. The principal limit to these projects is the high cost of geothermal drilling, which is justified only when large scale utilization is possible.

Hydropower already accounts for about one half of the electricity generated in LDCs. Large hydro resources are known in many countries; their exploitation, however, is made difficult by the remoteness of the sites with respect to the location of the potential users, by the high investment costs involved, and in some cases by competing uses of the water. Although they have a higher unit cost, small plants (the so-called mini and micro-hydro) may be more attractive if they produce electricity close to the user. Such plants could provide electricity to areas not connected to the general grid; in other cases, they could feed the grid, and recent projects have shown the feasibility of several small hydroplants with no personnel in attendance, remotely controlled from a central location.

Non-conventional uses of biomass are another interesting and highly debated chapter. The largest and best known programme in this area is that carried out in Brazil for the production of ethanol from sugar cane and other crops. The alcohol thus produced can be used for motor vehicles either pure or in conjunction with gasoline (gasohol), or for industrial applications. Other developing countries have started smaller programmes in this area. The experience from these programmes has not been fully positive, in the sense that their success is critically dependent on the distribution and concentration of the crops, on the transportation of the materials, on the integration of fermentation plants in the overall process, etc. In addition, careful consideration has to be given to the alternative uses of the crops or of the land, in particular for nutrition. This dilemma does not apply only to non-conventional uses of biomass. Energy competes with food even in the case of land use for forests.

Biogas production is now widely diffused in countries such as China and India. The performance of these generally small plants and the utilization of the products can be improved with modest investments. Other technologies for biomass utilization at different stages of development and diffusion include direct combustion of agricultural wastes for the production of electricity or the co-generation of electricity and heat; gasification and pirolysis and the hydrolysis (either chemical or biological) of cellulose and emi-cellulosic wastes. Some of these techniques may be improved in the future as a consequence of the present boom of biotechnology research.

As we all know too well, technology is only a part of the problem and generally not the most important part. Institutional, managerial, educational, political, financial aspects are more likely to represent difficulties and constraints. LDC governments and institutions can do many things to overcome them. In most cases they will also need support and action from industrial countries and from international organizations.

Touching briefly on some of these aspects, energy strategies must be fasbioned by the countries concerned, even if they need to use methods and advice from outside. Such strategies should start from an assessment of actual supply and demand, and an evaluation of their possible evolution, making use of local opportunities, resources and technologies as important factors in determining conservation, evolution of consumption of the various sources, and trends in industrialization. Although prices need not always directly reflect the immediate cost of energy, policies that result in prices distant from the ultimate estimated cost of energy sources are bound to induce developments that cannot be sustained indefinitely.

Training is an essential part of any development project, be it energy or something else. Technical and managerial skills must be improved on a large scale if these programmes are to be successful. Human resources constitute a nearly unlimited reservoir of development, whose exploitation is of the highest priority.

Technology transfer is a theme that has received increased attention in recent years. Training is the backbone of technology transfer, but direct involvement of industries of both receiving and donating countries is generally implied. Legal aspects are a not secondary source of problems. Advice from international institutions may be very useful in encouraging appropriate initiatives and discouraging those that are not compatible with local capabilities or needs.

Most, if not all, of the problems I have mentioned here are well known and are frequently discussed at international meetings. Major conferences examining this subject have concluded with recommendations and action plans. It may seem optimistic to hope to achieve with our small group results that have not been obtained so far. Yet I believe that the perception of the centrality of the problem of poverty and development, and within it of the energy problem, that is common to all of us, our sense of individual responsibility defending us from unacceptable pressures, the unique prestige of our hosts, may encourage us to come forth with concrete proposals that, while based on the reality of facts, contain the bold strength of simplicity.

UMBERTO COLOMBO
President ENEA, Rome - Italy

DEVISING AN ENERGY POLICY FOR DEVELOPING COUNTRIES

NECESSITY OF A GLOBAL APPROACH

JEAN COUTURE
Honorary Secretary General for Energy (France)
Chairman of the French Institute of Energy (IFE)

0. SUMMARY

0.1 There is a marked correlation between a country's availability of energy resources and its development. However, energy consumption is not an end in itself; it should be put to the best use. The problem pertaining to the consumption of different types of energy and of access to supplies can only be mastered hy taking account of all the internal and external sectors which have connections with the energy sector.

0.2 Firstly, developing countries' present position frequently displays some well known aspects, e.g., deforestation. However, the diversity is so great that solutions must be adapted to extremely varied ranges of scenarios and trends.

The example of a recent survey carried out for the Government of Mali highlights the main stages of the discussion below.

0.3 It may be tempting to base a strategic plan on sub-sectoral analyses of the different forms of energy, but this, in our view, would be a mistake. The problems would be set out in fragmented form and the solutions could well deviate markedly from a reasonable optimum. Needs must be examined first (final needs of course) and viewed in terms of their predictable trend in the light of the main development choices adopted.

Different energy production scenarios will be examined to determine which are desirable and which conditions they should respect to be effectively implemented.

0.4 How to define the energy strategy to recommend to a Developing Country?

Despite the often coarse nature of the available statistical data, one should first obtain a picture of the state of the main problems affecting the energy sector. A summary energy balance can be drawn up for the various sectors of consumption, taking account of the nature of their supplies, by collecting and cross checking all the available data.

The next step is to identify the trend of demand in each of these sectors, either its spontaneous growth, or as affected by the present or future action which will or should flow from voluntary decisions. At this stage it will of course be necessary in particular to examine the benefits and costs attending measures to improve efficiency, energy substitution, etc. Most often, first series of iterations will be required.

0.5 The problems of supply should then be investigated starting with the availability of national production. The expected results should once again be comparable with the costs to be faced. The possible scenarios should be assessed over time, random variations allowed for and priorities defined. The flexibility of the scenarios envisaged will naturally be a major aspect of the assessment which will follow.

0.6 The final component of the strategy is the establishment of detailed medium- and long-term energy balances as well as what may be viewed as supporting measures:

— pricing policy, taxation, subsidies;

— institutional aspects;

— vocational training.

It will also be necessary to place major emphasis on the external aspects of the strategy to be recommended, in particular as regards its effects on the foreign balance, the cooperation that may be sought, and the long term financing of resource development.

0.7 It is easily seen that the process as a whole cannot be linear. Loops and iterations will arise frequently. One cannot expect to be able to explore every possible configuration to adopt the best one. The costs and benefits are often not easily quantifiable, but the qualitative factors cannot be over-looked. The scenarios sketched out should allow a competent and attentive team to select the directions which best reconcile the possible with the desirable, and then to follow up and possibly modulate the effective implementation of the choices made.

1. Introduction

1.1 Examining any comparative study of the economies of different groups of countries, one cannot fail to be struck by the extreme diversity of per capita energy consumption. I need only refer among other things, to the graph which it was my privilege to present here in November 1980, and which clearly illustrates this dispersion.

Obviously, several factors each providing a partial explanation must be taken into account. Climate and the use of "non commercial" energy sources figure high on the list. Be this as it may, there is a marked correlation between the level of development of the various countries and their per capita energy consumption. It would follow that insufficient energy supply can hamper the development — which is agreed worldwide as a priority of the least developed countries (LLDC'S).

It should be borne in mind that needs are to be measured in terms of "useful energy". It is at least as important to concentrate on improving the transformation processes as to ensure the supply of raw energy.

These general remarks are enough to justify the need for an overall strategy enabling each country to cope as well as possible with the various and sometimes conflicting requirements which emerge throughout the energy chain, as well as those relating to the links between the energy and the other economic sectors.

1.2 It can immediately be seen that this can only be done by taking account of all the available data, and appraising the impact of contingencies, in order to define medium- to long-term objectives, together with the successive steps to be taken to achieve them.

The effects of the specific features of the energy system must also be taken into account, in particular:

— the very long "time constants" involved in many of the decisions to be taken;

— interactions between the various forms of energy and between supply and use;

— the reciprocal influences of each energy production sub-sector and the general economic and social trend of the country.

1.3 It is often asked whether government policy should be defined in terms of "energy planning", "the mastery of energy choices", or "incentives" which can correct market signals as required or reduce the sluggishness of response.

This debate is mainly theoretical. Experience shows that in each country, large or small, the Government, whatever its form, should keep economic operators informed as to the main components of an energy policy:

— what objectives should be taken as desirable in the light of the main economic and social choices made?;

— what are the stages, procedures, contents and methods of the energy strategy?;

— what resources are to be applied to meet these objectives, while safeguarding enough liberty of action in case of need?.

In this regard, it should be underlined that it is impossible to draw up a set of immutable regulations. The Public Authorities of a given Country are almost powerless to act against broad World economic trends, in particular those affecting prices and the availability of different energy resources. It is therefore a matter of prime importance that the decisions taken leave ample room for flexibility in the system envisaged.

1.4 I recently had the opportunity to apply the considerations presented here in the course of an energy planning survey performed for Mali. The report has just been submitted to the Government of that country, and the discussion below will refer to it as required to help shed light on the methodological approach followed.

I would like to acknowledge the invaluable assistance of Arnaud de Bresson (1), who participated in the planning survey, in the presentation of this paper.

2. Framework and objectives of an overall energy strategy

2.1 *Context of the energy position in developing countries*

May I first recall that although the energy crisis of the industrialised countries dates back to 1973 it made itself felt earlier and more fundamentally in developing countries.

2.1.1 Historically, many of these countries have had virtually no endowment of *conventional energy sources*. This has been a severe

(1) Economist at *Trans Energ* (IFE).

constraint on their development. The successive oil crises which occurred after 1973 have only added to their difficulties in a period in which energy consumption was rising sharply: an increase of 3.5 million barrels of oil per day for all developing countries between 1973 and 1981, while consumption in OECD-member countries decreased by 4.3 million barrels per day over the same period (2). Even if a major effort is made to save energy or make substitutions (3), higher future demand in developing countries is inevitable, and is basically linked to the process of economic growth.

2.1.2 A crisis generating at least as much concern in the developing countries is affecting the sphere of traditional energy sources (which is known to represent some 90% of the developing countries' energy consumption). The rapid reduction in wood resources is causing particularly serious problems. The real solution is not technical, but is associated with overall economic growth, and more specifically, with the transition to commercial or substitute energy ("new" energies, biomass).

2.1.3 In examining the time situation of the developing countries, whether in the light of present difficulties, or in other contexts, it is important to grasp the extreme heterogeneity that prevails in terms of available resources, energy uses, and the characteristics of economic development.

There is a considerable difference between, e.g., India with its 660 million inhabitants and the sparsely-peopled African countries; between the "newly industrialised" countries such as Korea and Brazil where annual per capita GNP is almost $ 1800, whereas the figure for LLDC's such as Bangladesh is of the order of $ 90 per capita; and, finally, between high energy producing and consuming countries such as Venezuela where more than 20 tons of oil per capita are consumed per year, and Mali where consumption amounts to 20 kg. Evidently, the nature of the problems associated with the development of the energy sector varies substantially according to the group of countries, the nature of demand (commercial or traditional), the available resources, and general economic or social conditions.

Annex I sets out a classification which may prove useful in explaining these disparities, many of which moreover are widening.

(2) Source: World Bank (1982).

(3) See: "The energy transition in developing countries", CM 1983. The rate of growth of commercial energy consumption could be slowed down considerably during the current period: + 4.5% per year against + 5.9% per year in the 1970's.

2.2 *The role of energy planning: objectives*

A vital priority for developing countries as a whole, in the light of these diverse positions and the on-going state of energy crisis (commercial or traditional), is for each country to design a new approach to its energy policy, integrating better knowledge of its own (domestic or external) problems with the quest for more consistent long-term solutions.

In general, energy planning is an indispensable stage linking the main objectives and general thrust of economic policy to the implementation of an investment strategy taking account of the real priority of needs and the necessity to mobilise resources to undertake the corresponding investments.

2.2.1 The main objectives of economic policy relate to such concerns as:

— the pace of economic growth to which energy needs must be adapted;

— national independence, in order to limit the volume of imports and thus the vulnerability to external events over which there is no control.

2.2.2 Planning in the field of energy will have to cast light on the directions which follow from these concerns by specifying:

— whether internal or external constraints hamper the satisfaction of energy needs;

— which objectives can reasonably be fixed for meeting demand and the development of the countries' own resources;

— what means are required to reach these objectives (financial, technical, regulatory, human, institutional, etc.);

— what roles should the different partners play to secure the desired result?

2.2.3 The process is the more indispensable in that, as seen earlier, decisions in the field of energy usually have a long-term horizon. For example, to build a hydro-electric power station takes four to six years from the initial decision to put it up, and once built, it will last an even longer period, more than twenty years. Contracts for the supply of gas also pre-suppose very heavy infrastructures and so must be signed for long periods. The characteristics of the transmission system or the construction of housing facilities determine the volume of energy consumption over roughly thirty years.

In addition, decisions relating to energy have financial implications for the long term. Given the emphasis on the ability to control consumption, the implementation of energy policy pre-supposes the participation of many actors (and not merely the large energy production and distribution enterprises). All these actors must participate in the decision-making process effectively to contribute to national energy independence through the choices they make.

2.2.4 In chapter 3, an attempt is made to specify the content and methods of this approach to the introduction of an indicative Energy Development Plan.

3. Contents and methods of energy planning

3.1 *Preliminary remarks*

3.1.1 Planning in the energy sector calls for scenarios and methods which are quite well known in industrialised countries whether the purpose is to integrate it into the general systems proper to countries with a centralised economy, or to define a plan of the type used in France to support a market-oriented economy.

When attempting to define the content of such planning or the elements on which to base an energy policy in a developing country, one realizes that the approach followed is different. There are two basic differences: in the data and in the choices.

3.1.2 The statistical materials available are utterly inadequate in most cases. The country's authorities are rarely equipped to collect statistical data whose nature and coverage are satisfactory. This does not mean that in the field of energy, some information, sometimes with quite a close degree of approximation, cannot be secured by different methods. The case of non-commercial energy sources is enough to show that rather imprecise evaluations are on occasion the best that can be had. External values such as GDP per capita are no better known.

Because their use would only be misleading, recourse to somewhat sophisticated models referring to the cross-relationships of the various economic parameters is out of the question. From a general economic point of view, the appraisal of the different choices is necessarily approximate.

3.1.3 Economic appraisal, it may also be noted here, does not carry the same weight in developing as in developed countries. Many ancillary factors can be and are often taken into account in the latter group to inflect a decision or accelerate or postpone its implementation: land development, social factors, influence on national defense, or even for the sake of prestige, all may enter into consideration on occasion.

Other than economic considerations have more of an impact in developing countries, where power is often more central and political concerns omnipresent. Many of these concerns, moreover, are justified when basic needs which are not covered, or even expressed, are to be met.

Consequently, the methodology followed should be adapted to choices that are often far removed from the classical choices concerning the costs and benefits of envisaged projects. It may also be remarked that these costs and benefits are not always defined in ways that can be appraised using traditional methods.

3.2 *The energy diagnosis*

Despite the difficulties mentioned above, the planning process should be founded on series of observations of the present state of energy demand and supply.

3.2.1 From available data and estimates which are as reasonable as possible, an attempt should be made to determine the physical quantities and the degree of approximation which may have been attained. The aim is to assess:

— energy consumption (final energy);
— the origin of supplies;
— possible availabilities (including energy saving "alternatives"), and to collect all the information that can be provided by examination of the statistical data and case studies.

An initial energy balance listing the different energy sources will be constructed on this basis.

3.2.2 During this work, it is indispensable to allow for the inflections detected in past trends, as well as the dominant factors governing the structure of energy demand and supply (there is a reason for reversing the usual order of the two words), meeting needs, which sometimes are close to the minimum for survival, should clearly be the major purpose of the exercise. The elements here are:

— from a general point of view, study of correlations, the elasticity of energy consumption with respect to growth (production or income), possible substitution of certain forms of energies for other sources;

— from a sectoral point of view: special attention to large consumers whose weight often determines movements in energy demand; as regards the trend of consumption, the implementation of certain new industrial projects may also have been the cause of substantial one-time shifts in energy consumption (similarly, by contrast, the decline in production or the shutdown of an establishment can cause a drop in demand unrelated to the general trend).

All these elements should allow a better understanding of the characteristics and factors explaining past trends in energy demand and supply. These relationships must be revealed to he able to establish the future trend of energy growth.

3.2.3 While performing the work, an attempt will be made better to grasp the main problems affecting the energy sector:

— the energy component of growth;

— impact on the external balance and the cost of possible energy imports;

— availability or non-availability of energy resources, shortages of traditional energy sources (wood);

— disequilibria between town and country;

— type of use and possihle wastage, etc.

Only this preliminary analysis will give guidance on the action needed to correct trends and remedy disequilibria.

3.3 *Projected energy demand and supply: investment choices*

The next aim is better to appraise the real trend of needs and available resources, in the light of the general objectives of energy development:

— meeting the needs of economic growth: needs in the industrial and transport sectors, more appropriate use of energy (including energy savings);

— improved equilibrium between urban and rural areas: meeting non-covered needs, policy for the penetration of electricity;

— materialising the national energy potential.

The strategy to be defined is not neutral vis-à-vis future trends. Indeed it is necessary to favour or by contrast inhibit certain types of energy demand or supply. The production of a medium- and long-term projection is indissociable from the choices made regarding consumption and investment.

3.3.1 Priority should be given to the study of demand. Energy policies have so far mainly favoured energy supply, which was understandable to the extent that the development of this resource was indeed the initial stage of the overall development of energy production. However, in addition to the fact that the real extent of needs has not always really been perceived, the successive oil crises have had at least two kinds of major repercussions which have contributed to transforming priorities: on the one hand, the sudden change in the relative cost of the different energy sources which alters the conditions of competition between the different components of the energy sector, and on the other, disequilibria of trade balances as well as the growing burden of investment. In other words, energy saving has become a necessity as has some substitution among the various energy sources. "Today's energy policy should take account of the required articulation for a policy of control of consumption, drawing the fullest value from national resources". (P.N. GIRAUD, *Planning and energy models*. Futuribles Colloquium, 1982). Furthermore, the possible interactions between energy demand and supply can bring about new prospects for the overall development of the energy sector.

3.3.2 The first possible approach to studying the prospects of demand is through traditional econometrics. The approach is to associate the variable, aggregate energy demand, with a number of explanatory parameters such as population growth, income level, the rate of urbanisation, etc. The relationships between these different factors are deduced, on the one hand, from the examination of past trends and on the other, from data reflecting the inflection of future trends (including the consideration of the objectives regarding resource exploitation or energy saving policies).

However, this approach in terms of trends is altogether unsuited to take care of the degree of uncertainty attaching to the explanatory parameters and makes no allowance for the envisaged effects of energy substitutions or new modes of economic growth. At best it provides for orders of magnitude and a reference framework.

3.3.3 By contrast, the analytical approach is based on detailed analysis of the dominant energy consumers in each sector:

— production: agriculture, industry, services;

— transport, and

— housing.

Despite difficulties in securing data, the sectoral approach was followed for the survey on Mali. For instance, the trend of household electricity consumption was studied at a disaggregated level taking individual urban and secondary centers. Several assumptions were made, such as the possible available output and general economic trends (changes in incomes). Industrial consumption was analysed case by case, at least for the large consumers, with special attention paid to the analysis of future projects (feasibility studies in progress) and several (low and high) hypotheses have been put forward, displacing the timing of the effective implementation of these projects.

Aggregate energy needs and their breakdown by energy source were then derived from the summation of the component basic needs of each sector for each energy source.

This approach ([4]) has the advantage of bringing the differentiation of the rates of growth of energy consumption by sector closer to reality and formulating clearly the hypotheses underlying the forecast. It is true that the frequently poor standard of data produces special difficulties for an analysis of this kind: The hypotheses or estimates involve varying degrees of accuracy.

Possible energy savings / substitutions for the same satisfaction of needs are also examined throughout the analysis:

— improvement in the use of commercial energy sources, penetration of the use of electricity from better-yielding energy sources;

— improvement in the use of traditional energy sources;

— optimization of choices in decentralised zones: local networks / interconnected systems, development of new energies / distribution of oil products, etc.

([4]) The approach was systematised through the Médée model designed by the Economic and Legal Institute of Energy at Grenoble, based on the explicit consideration of dominant social, economic or technical factors of demand. Aggregate consumption is decentralised into homogeneous modules (same use of energy, same economic actor or activity, same physical context). The trend of demand flows from the simulation of changes affecting these dominant factors. It should nevertheless be remarked that detailed information on each type and stage of consumption is required for the application of this model, which all but rules it out for developing countries.

The analysis of investment choices will later have to take all these possibilities into account.

At this stage of consumption, we will take once again based on the case of Mali, e.g., the study of fuelwood consumption scenarios. In this area, the two factors to be examined are the rate of growth of population and the rate of introduction of improved hearths for household use. Regarding this point in particular, for the hypotheses adopted for the rate of introduction, consumption in 1992 compared with 1982 declines by the following coefficients: 1.22-1.07 or 0.99 (i.e., a decline in consumption in absolute terms). The estimates made by the mission give an idea of the potential savings of wood:

Hypothesis	1992 Percentage of new hearths in use	Saving on consumption
A	30	6%
B	60	18%
C	80	30%

Thus the prospect of a stabilisation or even a reduction of fuelwood consumption in absolute terms within the next decade may be envisaged, providing suitable improved hearths are introduced rapidly (5).

3.3.4 From this basis, *the second stage of the work consists of predicting energy supply and analysing the investment choices in detail.*

As indicated earlier, the profound changes in the conditions of competition between the different types of energy meeting the same final use necessarily imply restructuring energy supply. The criteria of choice among the energy types must allow both for their economic aspects and such less quantifiable aspects as independence from foreign imports, minimum vulnerability, maximum flexibility and the magnitude of external effects on the overall economic variables.

3.3.5 *The classical approach* is based solely on the cost/benefit ratio of the energy produced (the economic and financial yield of investment

(5) Report on Energy Planning in Mali. « Trans Erg », March 1984.

projects). Most major electricity producers in industrialised countries have models available which enable them to optimize their share of output and distribution with respect to a given trend in the demand for final energy. In developing countries such as Mali, projects have to be analysed case by case, selecting investments (or sequences of investment) which optimize the cost price of the energy produced, i.e., the sum of capital expenditure and operating costs per project, for instance in comparing the cost of electricity produced by thermal and hydro-electric plants; (a complex analysis was undertaken in Mali of several general investment possibilities including various combinations of thermal and hydro-electric generation to meet the same needs in 1992); or, in an altogether different field, the comparative study of conventional diesel motor pumps and the possible use of generating sets producing renewable energy:

Comparative cost per m³ of diesel motorpumps and solar photovoltaic pumps.

	Diesel generator + immersed electric pump	Photovoltaic pump 1300 W crest	
Annual volume pumped	12 600 m³	11 500 m³	
Investment · generating set + pump + pumping cabin · photovoltaic pump	125 000	270 000	
Annual amortisation at 10%	duration 4 to 10 years 24 900	duration 10 years 43 900	 15 years 36 000
Annual operating costs: · fuel oil*, lubricating oil, labour, maintenance · periodical maintenance	37 600	8 000	8 000
Total annual cost	62 500	51 900	44 000
Cost price per m³ pumped (excluding the structure of the facility and distribution)	4.95 F per m³	4.50F/m³	3.80F/m³

* Fuel oil: 6 FF per liter (including storage)
(source: « Trans Energ », Mali survey - 1983).

The aim is thus to select projects which prove most feasible, technically: still taking Mali as an illustration, a clear choice was made in favour of development of small hydro-electric plants. The development of solar photovoltaic equipment is also an "interesting" approach but capital costs are still very high and limit its application.

3.3.6 This broad initial, mainly quantitative, approach has some evident limitations. In particular, it has contributed for too long to the failure to meet the needs of the rural economy — including the most basic needs, which are more difficult to satisfy by traditional investment projects. Even today, consideration of major projects such as electric interconnection is undertaken to the detriment of projects which are more appropriate but also more difficult to specify, for instance, the use of wood to produce heat or the introduction of micro hydro-electric plants. Some of these projects, whose unit cost is higher, have basic advantages in terms of broad objectives such as the exploitation of national resources or energy independence.

The projection of supply and investment choices necessitates assessment of *the impact and "value" of each project or type of energy on the overall economic variables*, such as employment or income redistribution as between towns and rural areas as well as the optimum general equilibrium of the balance of accounts. The French consultancy firm SEDES has systematised this approach by the "method of effects" which is, however, fairly difficult to implement. This method basically consists of reintegrating energy demand/supply data into the framework of overall macro-economic data so as to study the indirect effects of the development of each energy source in successive concentric circles. This presupposes that the macro-economic accounts of the country in question have already been systematised, but few developing countries have as yet such perfected instruments available.

Be this as it may, the orientation of the approach can be taken over: it should be underlined that in the surveys in the field, account should be taken as far as possible of all the factors characterizing the general objectives of each country's economic and social development.

3.3.7 These objectives include encouragement of the transfer of technology, which is a major chapter of the relations between the developing and industrialised countries. The developing countries would like to have access to modern efficient advanced technology. This legitimate desire should be taken into account in the process of investment choice.

However, the transfer of techniques should above all meet the environmental constraints of each country, and these constraints often differ totally from those prevailing in industrialised countries. The narrowness of markets, the insufficiency of infrastructures, the shortage of skilled personnel and the choices made regarding overall economic and social development all must be taken into account, and they impose a degree of progressivity in implementation. For the projects selected, it is of prime importance that the supply of equipment be accompanied by the relevant training (technical training and know-how).

3.4 *Establishing the overall energy balance*

3.4.1 The outcome of the analysis of energy demand/supply forecasts is the construction of an overall balance sheet statement which recapitulates the present and potential future position of the energy sector as a whole. The aim of the statement is to provide a coherent framework for the follow-up of energy planning. It is used to determine:

— the trend of energy demand and supply, indicating the breakdown of consumption by energy source and sector;

— the impact of action to make energy savings or substitutions (several scenarios can be envisaged; their effect will be quantified in M. Toe);

— possible shortfalls in meeting demand (and the subsequent imports).

The overall framework set out below illustrates the expected outcome and its corresponding analytical possibilities.

3.4.2 However, in establishing the energy balance sheet, it is found that almost all *energy data collection systems* have major shortcomings.

Data collection is scattered and largely incomplete in most cases. Energy producers, importers or distributors are the first source of information on data relating to commercial energy sources. They often do not have adequate resources for the production of homogeneous, timely statistics.

A fortiori, there is even less information on non-commercial energy sources: very few countries have data on fuelwood and charcoal consumption especially in decentralised zones; but we have seen how substantial is the share of this consumption in the energy balance of many countries.

The studies performed in Mali or other countries were based on very general estimates and it seems urgent to render them more specific.

Presentation of the energy balance involves converting all consumption and production, into a common unit (in general, tons of oil equivalent). Leaving aside certain difficulties pertaining to commercial energy sources (especially the extent to which thermal generation is drawn on as a function of effective yield), the major problem, once again, relates to traditional resources and consumption for which the coefficients may vary to a substantial extent.

3.4.3 In summary, having an energy balance thus requires a substantial effort to improve the statistical tool. Its regular availability will allow for faster analyses than the use of complex models of energy supply and demand.

4. Supporting measures for overall energy strategy

In addition to forecasting demand levels and investment choices, the overall approach to energy strategy also involves sets of recommendations regarding price policy, improvement of the institutional framework, and training.

4.1 *Price policy*

Price policy is one of the basic tools for effective management of energy demand and supply. It should be designed as a long-term instrument, closely linked to the overall planning objectives and decisions on investment.

The structure of prices for each type of resource is dependent on various components:

— the value of raw material purchases;

— the payments for different services: producers (or importers), distributors and retailers;

— the (positive or negative) impact of fiscal measures: taxes and subsidies.

Each of these components should be examined in detail and the necessary changes studied to meet the three broad objectives of:

More rational management of demand. This implies that consumer demand settles at a level reflecting "truth in pricing", allowing for a possible reduction of the energy component of growth and better use of available resources. Prices are determined on the basis of cost/benefit analysis for each type of energy and the economic opportuneness of development of a particular resource.

Satisfaction of social requirements, especially in the coverage of the consumption needs of the most deprived groups. This may necessitate a modification of some tariffs in favour of certain groups of consumers and therefore of some specific products (lamp oil, low voltage electric current, etc.).

Finally, the viability and autonomy of producing firms. Price policy here should basically aim not to impair investment and the development of national resources.

To reconcile these partly conflicting objectives sometimes requires difficult allocative decisions, the more so as other more specific goals are also involved: fostering regional development (e.g., through electrification), aid to certain priority sectors (heavy industry or exporting firms), etc.

4.2 *Institutional aspects*

A major handicap of developing countries is often the absence of a coordinated and effective decision-making body for the energy sector as a whole. The existence of many administrations or sectoral "authorities" sponsored by various agencies, the lack of cooperation and coordination, and the insufficiency of skilled staff are factors which work against an effective approach to energy choices.

The creation or reinforcement of a Ministry of Energy with control over the whole sector and the resources to take efficacious and dynamic action is a major step (involving provision for personnel, administrative and financial resources). The Ministry will be responsible for coordination with the other Ministries having an interest in decisions on the energy sector (Ministry of the Plan, Economy and Finance, Industry, Agriculture, Water and Forestry).

Detailed recommendations were made in this regard for Mali, including the determination of staff requirements.

4.3 *Training needs*

Adequate training programmes should be designed as a priority for the development of these structures.

As I have noted on several occasions, government departments and professional organisations are often staffed by an inadequate number of competent executives to cover the whole range of the economic and technical problems relating to energy. As regards energy planning itself, providing training should be the major concern. Training should be more concrete and include applications. It should be extended by competent universities and the bodies in charge of energy, producers and distributors. The training courses should cover all the questions relating to:

— the analysis of demand: the trend of needs and of effective demand; the pricing of energy and economic or social constraints;

— the appraisal of projects: the capital or operating costs of hydroelectric power stations, refineries, investment in new and renewable energies: analysis of economic and financial returns;

— the technical and economic problems of energy supply and distribution;

— the micro- or macro-economic approach to substitution between types of energy — interactions between demand and supply; rational use of energy, etc.

In the case of Mali, several training courses were carried out in France by engineers and economists working for the Ministry responsible for energy, by official departments, and several energy producer/distributor organisations. These courses thus strengthened the competence of executives dealing with energy with a view to laying the foundations for a more coherent structure for the sector as a whole.

Conclusion

Having described this initial approach, one which requires further thorough study of the methodology and of certain new paths to be explored for the optimization of energy decisions, it is our hope to have demonstrated the interest of and the very great need for the overall study of energy strategy for developing countries at large.

The basic objective is to reach more rational choices over time and in "space". Firstly, over time, since — as mentioned earlier — decisions relating to energy take time, whether the completion time of projects or for the economic lifespan of the equipment installed. Secondly, in "space", in the sense that it is more important than ever to select the projects that are really feasible and really useful amongst the many projects and studies put forward from all sources. Still in "space", the new approach aims to discard isolated choices in favour of an "integrated" policy, with a better approach to needs and better combination of resource uses to satisfy these needs.

Drawing up this overall approach and the performance of serious studies in support of it are also the best way of mobilising funds — including the assistance to be expected from the developed countries and international organisations.

ANNEX I

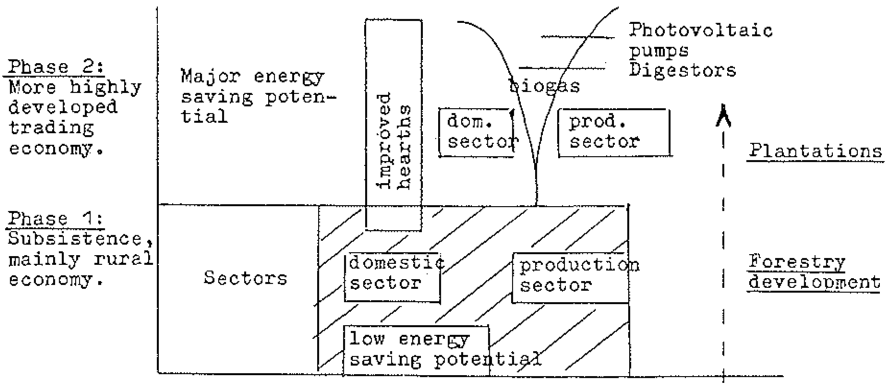
An Attempted Classification of Developing Countries

Zone No 1: Countries in which development is difficult: Black Africa; the Indian sub-continent (excluding India).

The problems in these countries are the transition from a subsistence economy to a more advanced stage of traded production. Present choices are governed by a limited number of priority actions, especially for easing the resource constraints. Effort including foreign aid should concentrate on these choices to avoid resource losses, and to venture some commitments for high-risk ambitious projects.

In this regard, the diagram below is particularly explicit.

Diagram No 1 - Choices of technology in the traditional rural environment.



Source: G. Foley - A. van Buren, World Energy Conference, November 1983.

Many projects envisaged, for instance, in the field of new and renewable energies should be studied with interest, with a cautious note to take account of their still experimental character and their cost (biogas process and photovoltaic pumps indicated at the top right hand side of the diagram). This assessment has been verified concretely in the case of Mali. As regards conventional energy sources, in the light of available financial resources, rational decision taking in energy related matters must certainly enjoy high priority.

Zone No 2: Heavily populated countries in the early stages of industrialisation: South-East Asia (excluding China).

As a first analysis, the positions of the countries under this heading are in very different situations:

Energy position \ Income level	Average income countries	Low income countries
Oil exporters	Malaysia	Indonesia
Oil importing countries	Korea	Philippines Thailand

As shown in the table, two countries, Malaysia and Indonesia produce and export oil, whereas the other three are net importers.

The common trait of these five countries (Korea, Indonesia, Malaysia, the Philippines and Thailand) is that they have all recorded very high economic growth since the end of the 1960's (+ 7.7% per year between 1970 and 1980). This very high growth has led to an even higher increase in commercial energy demand (the elasticity of consumption was well above unity for the period 1974 to 1981: approximately 1.2). The major problem is the oil bill:

	Energy Imports (as a % of export earnings) 1960	1980
Korea		38.0
Philippines	9.0	41.0
Thailand	12.0	44.0

Source: World Bank - 1983 report.

The exporting countries themselves are in a position in which consumption is rising faster than production, with a predictable reduction of available reserves and export proceeds.

Thus, in all cases, these countries will be led to rethink their long-term objectives of economic growth and energy development. Thailand, for instance, endowed with gas resources, has done much energy planning work since 1981 (Energy Master Plan for the years 1980 to 2000, with aid from the Asian Bank and UNDP). Korea and Indonesia have undertaken broad energy saving programmes in industry and transport with the help of Trans Energ and French bilateral aid. Malaysia is turning to the implementation of adequate methods to make more rational energy-related choices and to launch actions for a more rational energy use. Priority is given by each of these countries to the adoption of consistent strategies of resource development and improved demand management (oil substitution, energy savings).

Zone No 3: Countries in economic transition: Latin America (excluding Brazil), North Africa.

For countries which have reached the stage of industrial economies, the disparity between known reserves and energy needs is certainly even greater. Very few of them have oil or hydrocarbons (Mexico, Ecuador, Venezuela, Algeria and Tunisia, whose resources are declining steeply). Hydro-electric potential is somewhat greater in Latin America, but has hardly begun to be harnessed. Proven coal reserves are substantial only in Colombia and Venezuela.

By contrast, commercial energy consumption has also increased through economic growth and through the increase in real terms of the energy content of production. Between 1960 and 1980, the rate of increase of energy consumption was 2% higher in Latin America than on average in other countries. North African countries have achieved very high growth (+ 7.6% on average) and commercial energy demand has risen even more (+ 10% per year). The corresponding elasticity is 1.5.

The clear consequence of this growing disequilibrium is that immediate priority should be given to action to foster rational energy use (energy savings). Colombia, Nicaragua, Peru, Morocco and Tunisia have undertaken major programmes to this end in industry and transport (programmes supported by Trans Energ and French aid). Energy planning as such will come in a second stage so that the general energy choices may be reviewed and improved: enhanced energy data collection, comparative studies of policies and substitute energy sources, modeling of energy production to better integrate the sector's development prospects into the general framework of economic growth. Some studies have been initiated to this end in universities or in regional organisations such as the OLADE.

Zone No 4: The "great powers" of the Third World: Brazil, China and India.

Each of these countries has its own characteristics; we need not return to them.

The three countries are more developed and also have reasonably advanced scientific and technical skills. Their development plans no doubt already comprise the aggregate approach to energy policy.

Nevertheless, further action is necessary to strengthen coordination between institutions and optimize choices, taking account of the special aspects of these countries' economic and social structures. As for industrialised countries, the continuation of methodological studies and results involves major stakes.

Zone No 5: The capital surplus oil producing countries: The Gulf countries, Saudi Arabia.

Given the abundance of resources in these countries, they are certainly less inclined to be sensitive to the need for specific energy programming action. Priority is most frequently given to the management of existing resources: the same is true of the different fields of economic activity.

However, it is manifest that the relative stagnation of oil prices today could lead these countries too to realise the need to make more rational use of resources.

DEVELOPMENT AND ENERGY

JEAN ROMAIN FRISCH
Electricité de France
32, rue de Monceau, 75384 Paris, Cedex 08, France

ANDRÉ BLANC-LAPIERRE
Laboratoires de Signaux et Systèmes
91190 Gif-sur-Yvette, France

Introduction

Energy is an essential component of development; it is not the only one; there is also: food, water, public health, agriculture, industry, education,... Moreover all the corresponding problems are tightly interwoven and most of the considerations worked out in this paper can be applied to these various components.

Chapter I provides some global data relative to the Energy in the Third World - present situation and long term forecasts.

Chapter II and III regard the problem of Energy and Development and its links with the material and spiritual future of mankind.

Chapter IV analyses the main difficulties the development must face.

Chapter V contains an attempt at suggestions.

I - Energy and third world: present situation and long term forecasts

The latest survey of the World Energy Conference (WEC), presented at New Delhi in September 1983: "Energy 2000 - 2020: World balance and regional stresses", gives useful information about the present and the future energy situation of the Third World, comparing it with industrialized countries' evolution.

I-1 - This study, the first global one to be really *decentralized*, has been led through the W.E.C. network of 80 National Committees, thanks to its status of independent non-governmental organization. The challenge was to give the floor to the specialists of the regions themselves so that they could elaborate in common, within each of the 10 regional teams which were set up (6 for the South), their own long term forecasts, under their final personal commitment and responsibility. *Seventeen international meetings* have been organized throughout the world, bringing together, during several days, *50 high level experts*, with the active support of *20 National Committees* and *10 international organizations.*

The forecasts were formulated within the framework of two scenarios of development: the first one (I), corresponding to the return to a rather sustained economic growth; the second one (II), to persistent economic difficulties.

I-2 - *The energy evolution is mainly linked to two factors: demography and economic growth.*

I-2-1 - The Third World represents a growing share in the world *population*: 67% in 1960, 72% in 1978, 77% in 2000 and 80% in 2020 (6.2 billion inhabitants, including China). From now to 2020, its population would increase by 3 billion people against 300 million only in the North, a ratio of 10 to 1.

I-2-2 - On the other hand, the Third World's share in the world *GNP* should grow from 18% today to 28-33% in 2020, according to the scenario.

I-3 - The *total energy consumption* of the Third World would increase much: from 1.7 Gtoe in 1978 to 3-4 Gtoe in 2000 and 5-7 Gtoe in 2020. Consequently, South, which represents today (non-commercial sources included) 24% of the world demand, might represent 35-40% in 2020.

But, the *per capita* situation is much different: the ratio between South and North energy consumptions hardly changes all along the period: 13% in 1978 and 13-17% in 2020. The inhabitant of the South might, in the best case, double his energy consumption by 2020: 1.2 toe as against 0.55 toe in 1978 (+ 0.6 toe) in Scenario (I). But, in Scenario (II), he could hardly reach 0.8 toe (+ 0.2 toe) whilst the inhabitant of the North would increase his own consumption to 6-7 toe (4.3 in 1978), + 1.6 to + 2.7 toe. We stay far away from any kind of catching up of North by South...

I-4 - *The South energy consumption will be supplied in a very diverse way.*

I-4-1 - The call to *non-commercial* sources (fuel wood and animal and vegetable residues), even if their share is markedly declining within the total South energy demand (56% in 1960, 37% in 1978, 10% to 18% in 2020), is not expected to decrease in volume: 0.6 Gtoe in 1978 and still 0.7-0.9 Gtoe in 2000-2020 despite the heavy pressure on environment.

I-4-2 - *Coal* would preserve its market share: 20-22% of the total needs all along the forecast period, mainly due to its continuous penetration in China and India.

I-4-3 - Hydropower and natural gas would meet a strong development. *Hydropower* could cover in the long run 11% of total Third World energy demand (7% in 2000, 6% in 1978) and account for 50-60% of the world hydraulic production. *Natural gas*: 14-16% of Third World energy demand in 2020 (6% in 1978), 35-40% of the world demand.

I-4-4 - *Nuclear* and *new energies* would only emerge in the long run, each around 5% of the total South needs.

I-4-5 - At last, *oil* consumption *can only grow substantially* (1 to 2 Gtoe in 2020 against 0.5 Gtoe in 1978). Consequently, South would become progressively the main oil consumer on the world scene, calling for 50-60% of the world oil demand in 2020 (33-40% in 2000) as against 18% in 1978. The oil producers' strategy can only be deeply affected in the long run by this change in the consumers' pattern, the more so because they politically claim to support and belong to South.

I-5 - *If one analyzes the 6 regions of the Third World which have been studied, one may appropriately divide South into two main zones*: the three *rapidly growing regions* (South 1), composed of Latin America, North Africa/Middle East and South-East Asia, which seem able to benefit a promising growth. The three other *regions* "in transition" (South 2), which are bound to meet persistent difficulties: Africa South of the Sahara (not including South-Africa), South Asia and Communist Asia. The table on the following page enlightens the respective situations of North, South 1 and South 2.

I-5-1 - South 2, which represents the Third World regions in the most critical situation, will hold 56% of the 2020 world population (4.3 billion people, the equivalent of today's total world population). But it still would only generate 8% of the world GNP and consume and produce only 15% of the world energy.

I-5-2 - Each inhabitant of South 2 would benefit a limited 400-600 $ 78 GNP in 2020, as against 2,700-4,600 $ for the inhabitant of South 1 and 11,000-15,000 $ for the one of the North. His energy consumption would in parallel increase very slowly: 0.5-0.6 toe in 2020 as against 0.4 today (South 1: 1.5-2.4 toe against 0.8 toe in 1978).

I-5-3 - The present and future situation of South 2 is quite alarming: might it be possible that half of the inhabitants of the world by forty years from now would be restricted to such low levels of economic and energy developments? Should such an explosive evolution occur, no doubt that the peace of the world can only be dramatically threatened.

A TRIPOLAR WORLD

% WORLD TOTAL	POPULATION			GNP			ENER. CONS.			ENER. PROD.		
	78	00	20	78	00	20	78	00	20	78	00	20
NORTH	28	23	20	83	77	70	75	67	62	58	58	57
SOUTH	72	77	80	17	23	30	25	33	38	42	42	43
SOUTH 1	20	23	24	11	16	22	11	18	23	27	27	27
SOUTH 2	52	54	56	6	7	8	14	15	15	15	15	16

QUANTITIES	(billion)		(000 $ 78 p.c.)			(toe/p.c.)			(toe/p.c.)		
	78	20	78	20(I)	20(II)	78	20(I)	20(II)	78	20(I)	20(II)
NORTH	1.2	1.5	6.2	15.4	11.2	4.3	7.0	5.9	3.5	6.7	5.6
SOUTH	3.1	6.2	0.5	1.8	1.1	0.6	1.2	0.8	1.0	1.3	0.9
SOUTH 1	0.9	1.9	1.1	4.6	2.7	0.8	2.4	1.5	2.2	2.7	1.9
SOUTH 2	2.2	4.3	0.2	0.6	0.4	0.4	0.6	0.5	0.5	0.7	0.5

II - Material and spiritual points of view

The problem of the Third World's development is indisputably one of the main problems mankind must face. In fact, it is tightly linked with all tbe other problems: demographic growth, hunger, economic growth, energy, unemployment, investment needs, impairments of the ecological equilibrium and, lastly, the problem of peace, in which the Third World unfortunately often serves as a pretext or as a battle-field for the superpowers.

From the purely material point of view, the solution of this prohlem is capital for the equilibrium of the world economy. It is normal for the money suppliers to feel concerned about the *profitability of each separate operation.* But this cannot obliterate the fact that industrialized countries as a whole must take into account the general interest resulting from each significant advance in the solution of the Third World's problem. *Unsolved questions are usually very expensive. In a general balance-sheet*, one must take into consideration all the potential expenses due to conflicts or hlocked situations resulting from uncontrolled stresses. All of that limits the notion of *individual profitability.* One must also point out the great interest, for the industrialized countries, of the Third World immense potential market, as a complement of their own market now reaching saturation.

Beyond the material point of view, the Third World's development poses a *spiritual problem*, that of the *respect of man* and of *solidarity.* Is this not a tonic challenge for our partly disillusioned societies unconsciously looking for a great *stimulating project*? Contrary to what can be observed today, should not this problem be a convergence factor between industrialized nations?

III - Energy and development

Energy is an essential component of development; it is not the only one: there is also *food, water, public health, agriculture, industry, education,...* Moreover, all the corresponding problems are tightly interwoven.

The sociocultural development is also strongly linked with all the above factors. The fact that the resources are strictly limited implies the exigency of choices. *The energy policy needs to be wisely included in a global policy.* Developed nations can give advice and help with the elaboration of that global policy, hut the main choices can be made only by the responsible people of the concerned countries.

Some examples of political choices originating — explicitly or at least in fact — from energy problems can be found below:

a) *Hydroelectricity and drought*

90% of the electrical power produced in the Ivory Coast in 1982 came from hydroelectricity. In 1983, the drought drastically reduced this essential component of the electrical power supply. In view of the corresponding financial problems, this country was obliged to choose between the installation of supplementary gas turbines and other important expenditures.

b) *Construction of large dams and power plants*

In the traditional systems of electricity production and distribution, it is empirically admitted that no single production power station should supply more than 10% of the total system distribution power. Furthermore in order to realize economies of scale, power stations of about 1000 MW — and even more in the case of nuclear reactors —, were constructed in industrialized countries. According to the rule quoted above, only very few developing countries could afford such power stations. In any case their construction implies an extremely critical previous study concerning all the problems they can create — necessity of a concentrated enough power use, therefore of dense enough industrialization, temptation of excessive urbanization detrimential to the rural areas which are essential to agriculture and nutrition.

In spite of the obvious interest of the hydroelectric production in developing countries, any big dam project must be very carefully balanced as regards not only the technical features but also all the political implications:

i) What will the dam be used for (electricity, irrigation)? Will its use be significantly profitable for the concerned country, or, on the contrary, will there be almost solely, a question of use of the site by a foreign company?

ii) What indebtedness does this construction imply?

iii) What modifications will result from this realization for the conditions of life in the country? People to relocate? Possible interruption in fertilizer lime deposits? Possible international problems connected with the flow of the river?

The big INGA Zaïre project can illustrate such questions.

Its total realization would supply 300 TWh/year [a little more than the total French supply of electricity]. The present equipment supplies 1200 MW [about 1/40 of the big INGA] which is only partly used.

IV - The difficulties of the Third World development problem

IV-1 - *The Third World is mainly located in tropical countries*

As pointed out by Maurice Guernier [2], the tropical nature brings an impressive set of "counter-productive" factors from the point of view of the Northern man. Temperature makes the work difficult. Heat favours microbe proliferation, thus making many illnesses more virulent.

Humidity or heavy drought results in increased difficulties and often lower productivity in agriculture.

Moreover, the natural desertification is often reinforced by excessive wood use and goat breeding. On the other hand, heating needs are smaller and this advantage remains even if air cooling is taken into account.

IV-2 - *The means of intervention must be adjusted to the possibilities and needs of developing countries.*

Any *global* approach will be adjusted to the *local situations. Proper solutions are often particular solutions; they require broad-mindedness, humility, a sense of dialogue and listening. The problems involved are not only economic but also social and cultural.*

Some *examples* will illustrate the gap existing between situations in developing and industrialized countries.

In Africa, electrification amounts to only 20%.

At the opening meeting of the 7th Convention of Union of Producers, Conveyors and Distributors of Electric Power in Africa [Libreville, 1981] (U.P.D.E.A.), the Minister for Mining, Energy and Hydro-electricity of Gabon, M. Divungi Di Dninge, expressed himself as follows:

"It is in a disquieting and ominous context that developing countries must, after their political independence, conquer the full command of their economic and social destiny. I invite you to think for a few minutes over the circumstances in which such mutation is occurring".

"The now industrialized countries have lived this mutation in exceptionally favourable circumstances: first, the complicity of a benevolent nature, climate, vegetation,... then, the existence of a long standing agricultural, artisanal and commercial substratum on which the industrial revolution was able to develop. Supporting this revolution and advancing with it, but at the smooth rhythm of the succession of the generations, a general education level and diffuse technological knowledge have been available (a very important help)".

"Last but not least, one must recall the huge contribution from the poorer countries, within the colonization, either in terms of man power or of raw materials and, particularly, of an abundant energy whose cost has kept decreasing in real value".

"If we consider, now, the situation of the majority of developing countries, and particularly in Africa, what do we discover? A nature that is hostile because excessive, which charges the highest price for each of man's conquests: on the one hand, the forest which is encroaching and impenetrable, with torrential rains and, on the other hand, the desert and the drought".

At the 29th C.I.G.R.E. meeting [september 1-9, 1982], Director Paul-Appendina analyses the difficulties of the *electrical networks interconnexion* in Africa.

"Two major obstacles draw insuperable limits to electrical network interconnexion: one deals with the huge lengths of the power lines in hostile environments — deserts or forests —, which make their construction and maintenance costs absolutely prohibitive, the other being related to tbe weak number of the points to be supplied — a few hundreds or a few dozens —, in view of the very great transportation distances". (1)

He illustrates this statement by giving some data concerning Gabon.

Area : 268,000 sq.km

Population : $0.56\ 10^6$ inhabitants [2 inhabitants/sq.km]

More tban 50% of the population live in a few main centres. Another typical feature: 85% of the area of this country is covered by an almost impenetrable forest.

He adds: "Some centres inside the country are supplied in such a way that the KWh costs more than 500 Francs C.F.A., and sometimes even 800 Francs C.F.A. and this by using classical thermal energy".

The fuel transportation cost can increase drastically the price of the KWh.

(1) Tests are being carried out in certain countries, to get, by capacitive coupling, a few kilowatts from a high voltage power line, so as to permit the supply of isolated consumers with simple equipment.

Finally, Mr Paul-Appendina draws the following two conclusions: "Firstly: over large distances, the hydro electric power supply is in some cases very difficult. Secondly: spot supply can reach prohibitive costs, intolerable for some poor countries, even using thermal energy".

IV-3 - *Complex ethnic issues* are often met; this is even more complicated by the fact that state borders were, in numerous cases, very artificially established.

V - An attempt at suggestions

The complexity of the problem creates the temptation of limiting oneself to facts and analyses, without attempting to try and advise. However, the stakes being high for humanity, everybody must, with the utmost humility, try to imagine and formulate suggestions. The following is a collection of several ideas, which probably exist in most of the studies devoted to this worrying but essential question.

V-1 - *Basic ideas*

V-1-1 - *The necessary respect for mankind*

The problem of development brings the question of respect for mankind to the fore. It underlies the moral health of mankind. We must protect ourselves simultaneously from the temptation of reducing this problem, *on the one hand*, to the mere questions of supply of raw materials and of energy... that of economic affairs, questions of influence, domination, political competition, *and on the other hand*, to attitudes of protest and of immediate political gains.

We must think about *the real underlying problems*, and over a long-term period. All being considered it is *after all the peace and harmony of the world which is in the balance.*

V-1-2 - *The problem of development and that of world-peace*

Under-development is a permanent source of tension which seriously menaces peace.

Furthermore, the problem of under-development can only be resolved in an atmosphere of peace. And at the same time, its solution can only progress significantly if the industrialized nations succeed in reducing their own disputes, and the Third World does the same with regard to internal tension.

We can only unite mankind by persuading men to build together. Could not development become part of a vast project for the unification of mankind?

V-1-3 - *The indispensable appreciation of the specific features and of the personality of the different partners*

The development of Third World countries cannot be obtained by the simple transposition of the systems existing in industrialized countries. Numerous differences, be they psychological, sociological, cultural or natural, and many operational and political difficulties, make this approach no more than a great illusion.

As the electrical engineers say: *Energy cannot be transferred without matching impedances.* With a view to this appreciation of these specific features, a pragmatic attitude must be adopted. Gigantism and artificial aggregates must be avoided at all costs.

Significant progress implies a general collaboration, in which the Third World countries, conscious of the necessity of their participation, will become capable of planning for their own problems; and the industrialized nations must make every effort to be capable of communicating to them the fruit of their experience, as well as their techniques, suitably adapted to the Third World needs and specific features, and carefully modulated by local imperatives.

The effort to be granted for the adaptation to the needs of developing countries in the realm of technology and of material developed in the industrialized countries, is of prime importance. This adaptation must be the result of close cooperation between technicians and those responsible in the two different types of nation. It also implies a great number of contacts and reciprocal openmindedness. It is most definitely the opportunity for setting up friendly relationships between the countries concerned.

V-1-4 - *The importance of balance between Agriculture and Industry or between Rural Life and Urbanization*

In his book "Tiers Monde - Trois Quarts du Monde" [2] (2) Maurice

(2) "The Third World - Three Quarters of the World".

Guernier notes that improvement in agricultural production must *come before* industrial development. It is through growth of agricultural productivity that it should be possible to allow workers to leave the fields for the factories, and by increasing the spending power of the rural world thus develop the demand for industrial products.

Unfortunately, it is practically the opposite movement which is generally observed in the Third World Countries. Little progress has been made in agriculture and the overgrown population, heing too dense for the fields, tends to escape rural life in order to crowd into the vast urban centres where unemployment is rife.

Within this same vein, we may note that if it is suitable to accompany the growth of towns with a supply of the necessary energy, and especially electricity, importance must be granted to the development of rural electrification wherever it may be possible.

The effect of any given choice of energy system on the balance between country and town must be carefully studied.

V-1-5 - *The two aspects of the time factor*

On the one hand, the urgency of problems to be solved, and the physical and technological time constants concerning equipment in energy (the basic unity is a decade for research-development, for the building of power stations, for prospection and the putting into service of oil-fields or coal-measures, for changes in industrial yards, for the adaptation of use of such and such type of energy supply...) mean that decisions must be made without delay. This is the "urgency of the future": there is not a moment to he lost. As Carroll Wilson wrote in the exergue of the Wocol Report (World Coal Study) [3] "Time is our most precious resource. It must be used as wisely as energy".

On the other hand, we should not be too miserly with this resource called time. Changes in habit and behaviour also have their time constants which must be respected to avoid serious perturbations. The industrialization of Northern countries took nearly a century. It is not reasonable to want to transfer, be it only a part of its results, over a period of one or two decades, to countries which are not ready for it.

Furthermore, time has also played a role in profoundly modifying the appearance of our industries and their say within human society, their role in the life of man. All must be done to save the Third World from having to pass through all the stages of our own industrial development — some of which were very difficult.

V-2 - *The importance of energy supply to non-oil-producing countries of the Third World*

In spite of progress made in the development of other sources of energy, in particular that of hydraulics, oil remains essential to development and even to everyday life in these countries. The considerable rises, however, in the price of hydrocarbon recorded since 1973, combined with the rise of the dollar, have severely hit their economies, especially those of the African countries, even more so than those of the industrialized countries.

So that these ideas may be clear, from 1973 to 1982, the price of one barrel of crude oil has risen from $ 3.6 to between $ 30 and $ 32, while the dollar has soared from 250 C.F.A. to about 400. Consequently, the fuel-bill of the following eleven African countries: Benin, the Republic of the Cameroons, Ivory-Coast, Upper Volta, Madagascar, Mali, Mauritania, Niger Republic, Central African Republic, Chad and Togo, has risen from 25,000 millions C.F.A. to over 300,000 millions (that is to say about 500 million francs to 6,000 million francs, or from 100 to 800 million dollars). This increased financial burden in everyday currency absorbs an average 2.5% of their G.N.P., and significantly increases their balance of payment deficit.

The situation of the non-oil-producing countries of the Third World is the most worrying.

On the one hand, it is wise that the industrialized countries reduce their consumption of oil thanks to their accumulated saving of energy, together with the growing use of nuclear energy and coal, as well as other sources of energy. This is, as it happens, the present trend. Fuel will thus be made available for the countries of the Third World.

On the other hand, the oil-producing countries must adapt to a new distribution of consumption, at the heart of which the share of the industrialized nations will be decreasing in comparative importance, while the needs of the Third World will become preponderant. The foreseeable evolution (most probable that is) implies a reset of the balance of the situation.

V-3 - *Guidelines*

It would seem reasonable that these guidelines should form around the following necessities:

V-3-1 - *A global policy beginning with urgent measures to put into immediate effect and going on to medium and long-term policy*

For example, the state of emergency created by the drought in the Sahel demands planification. A plan was presented at Geneva for 8 countries (Cabo Verde, Senegal, Gambia, Mauritania, Mali, Upper Volta, Niger Republic and Chad) by the U.N.P.D. (the United Nations Programme for Development) and the Cilss (Comité inter-états de lutte contre la sécheresse au Sahel); it contained both emergency measures (food supplies, cattle fodder, health protection, roads to insure transport of food, water supply for the population and the livestock...) and medium and long-term projects, designed essentially to stop the advance of the encroaching desert: stabilization of the dunes, forest plantation for firewood, integrated development between forest and agricultural zones, creation of small industries related to forestry and other forestry exploitation.

There are so many pressing problems in the Third World that long-term and even medium-term projects are generally neglected. And what is more, this concerns regions where "the urgency of the future", already quoted in V-1-5, is of prime importance. Planning, even if risky, is necessary.

It must have global impact as all problems are interconnected: energy, water, food... population distribution... life-styles...

V-3-2 - *A global policy elaborated with the most effective participation of the countries concerned*

As has already been noted (see III, p. 39) the essential choices can only be made with the agreement of the countries concerned.

A most important point is brought to the fore by the fact that *this policy must be adapted to the particular needs and the personal standards of living of the countries concerned by it.* This implies an *analysis of local specific features, a restatement of the criteria different from those of the industrialized nations*, and the study of the problem of *adapting technological transfers.* All this planning must closely associate the various collectivities or groups concerned, be they local, national or international...

It will be that much easier to unite efficient interlocutors when the problems of education will have made some progress (see V-3-4, p. 48).

V-3-3 - *Policy fostering regional cooperation*

These types of cooperation are often difficult and come up against numerous obstacles, but form such a compulsive stage in the development process that everything must be done to encourage it. The large political set-ups are certainly harder to establish than groups aiming for limited concrete objectives. Brazil, Colombia and Mexico have elaborated a project for a three-sided joint management scheme of their coal resources. Mexico and Venezuela have got together over the past two years and committed themselves to insure the flow of oil to the Central American countries.

The area concerning energy lends itself well to the undertakings of regional cooperation. The building of certain dams may interest several countries. Finally, in spite of the very real difficulties underlined in paragraph IV-2 (pp. 41-42) electric inter-connections may develop under certain conditions, in particular in the case of a joint hydraulic exploitation.

Student formation can also easily give rise to regional cooperation. The Interafrican Electricity College founded by the U.P.D.E.A., Union of Producers, Conveyors and Distributors of Electric Power in Africa, provides an excellent example. This school, established at Bingerville, near Abidjan (Ivory Coast), has at present 140 students from 16 different countries.

V-3-4 - *Policy in favour of education and a progressive take-over of responsibility for their own problems by the developing countries*

This encompasses not only education in the traditional sense (teaching, courses...) but also formation resulting from effective participation in various projects and from association with corresponding working groups. Everything which encourages the forming of managerial personnel is extremely important.

The decentralized attitude to studies of the World Energy Conference (WEC) joins this vein of thinking: it does its best to let the inhabitants of the various regions speak for themselves, by letting them express their own point of view on their future as far as energy is concerned, rather than force upon them a model and exterior results (80 National Committees, representing producers as well as consumers of energy in the North and South, the East and West).

On another scale, this is also the perspective adopted by S.O.S. Sahel with its action for *water* (1550 village pumps, 50 motorpumps, 15 solar energy pumping stations, construction of levees in rural areas) and for *vegetation* (preservation of water and soil, replantation of trees). This association provides the material and the initial expertise, but mobilizes the inhabitants concerned for the installation works, and prepares them for the maintenance, trying to render them capable of dealing with problems of replacement whenever they arise.

* * *

The problems to be solved are considerable, but the future of mankind depends on their solution. But what an exciting task with which to fire enthusiasm, especially in the minds of young people today who are often seeking a goal! This task requires a great deal of imagination, much open-mindedness and deep-seated charity. It touches one of the most sensitive areas where peace is concerned. *It depends a great* deal on following two basic things: *the promotion of all under-developed countries*, and *the promotion of the rights of man.*

REFERENCES

[1] *Energie 2000-2020, Equilibre mondial et tensions régionales.* 12e Congrès de la Conférence Mondiale de l'Energie. Commission de Préservation, par JEAN-ROMAIN FRISCH. Publié par les Editions Technip, Paris 1983.

[2] *Tiers Monde: Trois Quarts du Monde.* Rapport au Club de Rome, par MAURICE GUERNIER, Dunod, Paris 1980.

[3] *COAL - Bridge to the Future* by CARROLL L. WILSON (Cambridge, MA: Ballinger Publishing Co., 1980. Harper & Row International).

ENERGY USE IN DEVELOPING COUNTRIES

JANE CARTER
Vice President, International Association of Energy Economists
International Energy Efficiency Consultants
Washington, D.C.

Introduction

The key role of energy in growth and development has only been brought into the mainstream of economic analysis comparatively recently. The development of the industrialised world was fuelled by cheap energy — coal, subsequently supplemented by gas and oil, and most recently by nuclear power. The abrupt change to a higher energy cost scenario with the oil price increases of 1972/73 and 1978/79 has led to a reappraisal of the inter-relationships between energy consumption and economic growth in order to facilitate the necessary adjustments in energy consumption and production patterns in developed and developing countries alike.

For the industrialised world, the problems of adjustment are difficult, but not unsurmountable. The existence of high levels of industrialisation and urbanisation, coupled with a relatively stable size of population, provides a robust foundation. However most developing countries are faced with the additional problems of rapid population growth; the need for structural change and accelerated growth to maintain and improve standards of living; shortage of technical skills; shrinking export markets as recession and protectionist policies have held sway in the developed world; and a daunting burden of foreign debt, much of which relates to heavy borrowing to finance the energy imports of the past decade.

The developing world draws a major part of its energy supplies from traditional or "non-commercial" forms of energy (wood fuel, farm waste, bio-gas, and so forth) — in the case of low income countries as much as a half. However, its reliance on commercial energy has grown with economic development — the share in global primary energy consumption has grown from 10% in 1955 to some 20% today, much of the increase being met by increased imports of oil.

A comparison of energy consumption and energy intensities in the industrial and developing countries is given at Table 1. Taking both commercial and non-commercial fuels together, it is estimated that the industrial countries consume nearly nine times as much energy per head as in the developing countries whilst their intensity of energy use (measured by useful energy consumption per million dollars of GDP) is twice as high.

In future, the energy consumption of the developing countries seems likely, as in the past, to expand at a faster rate than in the rest of the

TABLE 1 — *Energy Consumption and Gross Domestic Product: 1973 Industrial Countries and Developing Countries*

	Unit	Industrial Countries	Developing Countries	Ratio of Industrial to Developing
1. Per capita total energy consumption (including rough estimates for traditional fuels and counting hydropower at equivalent primary fossil fuel rates)	Metric Tons of oil Equivalent (toe)	4.22	0.48	8.8
2. Real GDP per capita (Kravis calculations)	U.S. $	3,343	520	6.4
3. Energy consumption per million dollars of real GDP	Toe	1,263	916	1.4
4. Assumed average fuel conversion efficiency	Per cent	50	35	1.4
5. Useful energy consumption per million dollars real GDP	Toe	631	321	2.0
6. Population	Millions	1,119	2,717	0.4

Source: Energy Consumption data based on J. PARIKH, *Energy and Development*, World Bank PUN 43 (1977). GDP data based on I. KRAVIS *et al.*, *Real GDP Per Capita for More than 100 Countries*, Economic Journal 88 (June 1978). Lincoln Gordon: Energy & Development, 1980.

world, partly because their economies are likely to grow faster and partly because increasing industrialisation and urbanisation will entail a rapid growth in usage of commercial forms of energy. Their share of world commercial energy consumption may rise to 25%.

The likelihood of renewed pressure on world energy markets in the 1990s (and even sooner if there is any prolonged disruption of supply) makes it imperative for both the developed and developing world to take action to increase efficiency of energy usage and supply and to develop indigenous supplies. Against this background, this paper examines the pattern of energy usage in the developing world, the possibilities for change, and the policies and instruments that need to be developed.

The Energy Profile of the Developing Countries

The 127 countries which make up the developing world comprise about three-quarters of the world's population (some 3000 million in 1977), and account for some 20% of the world's real economic output. It has been estimated that they contain over two-thirds of the total probable reserves of oil and gas, although only one-fifth of the coal. They are the world's main suppliers of oil.

However, these statistics conceal a wide diversity of circumstances. At one extreme are countries mainly dependent on subsistence agriculture and livestock tending — at the other extreme are countries such as Korea and Brazil, with a large and dynamic industrial sector and the highest per capita incomes. And in between come the heavily populated but relatively poor countries such as China, India and Pakistan, with a substantial and growing industrial sector superimposed on a primarily agricultural and low-productivity economy.

Perhaps the central distinction however is between the Oil Exporting Developing Countries (OEDCs) and the Oil Importing Developing Countries (OIDCs). Table 2 shows how the developing world is divided on this basis and the degree of dependence on oil imports of the OIDCs. Some 28 are net exporters of oil, although several of these (in particular China, Indonesia and Nigeria) could absorb most of their exportable surplus over the next decade. But the vast majority depend on imported oil. Whilst some have the potential to become self-sufficient in this decade (e.g., Chad, Ghana, Pakistan) the dependency of others (e.g., Brazil, Korea) could increase.

Table 2 also shows countries which are already seriously short of fuel wood or heavily dependent on fuel wood and other traditional sources of energy. These include a large majority of the low income countries, most of which in addition are almost totally dependent on oil imports. This is in effect a double energy crisis.

The dependence on wood varies with income. Increasing prosperity is associated with increasing efficiency in fuel use and diversification of supply. This is illustrated in Table 3, which shows for a number of countries, most with predominantly rural populations, their per capita incomes and the proportion of national fuel needs supplied by wood. This does suggest a move away from fuel wood use as incomes rise.

It is expected that the next stages of economic growth will be accompanied by a faster growth of commercial energy consumption. The energy demand of the developing countries, particularly the OIDCs, will, of course, be dependent on the development of the world economy. A recent World Bank study suggests that from 1985-95 there will be a faster annual growth in GDP in the developing world (5.5%) than in the industrialised countries (3.7%), against a background of an overall annual increase of 1 per cent in oil consumption and 1.6 per cent in real oil prices.

In consequence, OIDC annual energy consumption is expected to grow at 5%, with only half this additional demand being met by imported oil. If energy conservation and national resource developments are successful, dependence on oil imports (as a proportion of total commercial energy use) could fall from 44% in 1980 to 28% in 1995. However, as Table 4 demonstrates, the increase in total imports of oil will still be substantial.

Broad Energy Options

This pace of progress depends on the effective energy policies being pursued in the context of the overall economic strategy. In the short and medium term, the efficiency of both energy supply and consumption needs to be increased. In the longer term, the development of indigenous resources, both of fossil fuels and renewables, will play a major role — for the poorest OIDCs even small-scale developments could substantially reduce import dependency.

Although improved energy efficiency could, in effect, become the developing world's "fifth fuel", it has to be recognised at the outset that

Net Oil Imports as % commercial Energy Demand ([b])	Net Oil Exporting Developing Countries		Oil Importing Developing Countries ([a])				
	OPEC Members	Non-OPEC	0-25%	26-50%	51-75%	76-100%	
	Algeria *Gabon* *Iran* *Iraq* *Kuwait* *Libya* *Qatar* *Saudi Arabia* *United Arab Emirates* *Venezuela*	*Bahrain* *Bolivia* *Malaysia* *Mexico* *Oman* *Peru* *Syrian Arab Rep.* *Trinidad and Tobago* *Tunisia*	*Argentina* *Colombia* Korea, Dem. Rep. *Romania* South Africa	*Chile* Mongolia *Yugoslavia*	*Albania* *Brazil* Korea, Rep. of Lebanon *Turkey*	Bahamas *Barbados* Costa Rica *Cuba* Cyprus Dominican Fiji Rep. *Guatemala* Guyana Ivory Coast Jamaica Jordan Malta	Mauritius Nicaragua Panama Papua, New Guinea Paraguay Portugal Suriname Uruguay
Countries with Actual or Potential Fuelwood Problem ([c])	*Ecuador* *Indonesia* *Nigeria*	*Angola* *Burma* *China* *Congo People's Rep.* *Egypt* *Zaire*	*India* Viet Nam, Zimbabwe	*Bangladesh* Botswana Mozambique *Pakistan* Zambia	*Afghanistan* Burundi *Ghana* Malawi Rwanda	Benin Bhutan *Cameroon* Cape Verde Is. Central African Rep. Chad Comoros El Salvador Eq. Guinea Ethiopia Gambia Grenada Guinea Guinea-Bissau Haiti Honduras Kampuchea, Dem. Kenya Lao PDR Lesotho Liberia Madagascar Maldives Mali	Mauritania *Morocco* Nepal Niger *Philippines* Sao Tome and Principe Senegal Sierra Leone Solomon Is. Somalia Sri Lanka Sudan Swaziland Tanzania *Thailand* Togo Uganda Upper Volta Western Samoa Yemen Arab. Rep. Yemen PDR
Population (in millions)	320	1180	820	210	245	395	

Countries shown in *Italics* are oil and/or gas producers. Table based on UN *World Energy Statistics 1978* (except for Bhutan, Botswana, Lesotho and Swaziland whose position in the Table is estimated) and staff estimates of fuelwood situation. Population data from *World Development Report, 1980* rounded to nearest 5 million.

([a]) Excluding countries with 1978 per capita GNP above $3000 and countries with populations of less than 0.5 million that are not members of the World Bank.

([b]) Imports 1978.

([c]) Countries were placed in this category if estimated

TABLE 3

Country	Wood as percentage of total energy consumption (%)	Wood quantity per head (t/year)	Proportion of population in rural areas (%)	GDP per head (1978$)
Angola	74	1.0	79	300
Benin	86	0.6-2.3	86	230
Burundi	89	0.2	98	140
Cameroon	82	0.96	65	460
Central African Empire	91	0.8	59	250
Chad	94	0.8	82	140
Chile	13.3	—	29	1410
El Salvador	37	—	59	660
Ethiopia	93	0.8	85	120
Ghana	74	1.0	64	390
Guinea	74	0.6	81	210
Honduras	45	—	64	480
India	34	—	78	180
Ivory Coast	46	0.7	62	840
Kenya	74	0.6-1.5	86	330
Liberia	53	0.7-1.5	67	460
Madagascar	80	0.6	82	250
Malawi	—	—	91	180
Malaysia	8	—	71	1090
Mali	97	2.1	80	120
Morocco	19	0.2	59	670
Mozambique	74	0.9	91	140
Nicaragua	25	—	47	840
Niger	87	0.5	87	220
Nigeria	82	1.0	80	560
Papua New Guinea	39	—	83	560
Rwanda	96	0.9	96	180
Senegal	63	0.5	75	340
Sierra Leone	76	0.8	75	210
Somalia	90	1.0	70	130
Sri Lanka	54	—	73	190
Sudan	81	1.2	75	320
Tanzania	94	1.4-2.3	88	230
Tunisia	42	0.2	48	950
Upper Volta	94	0.5	91	160
Zambia	35	0.8	62	480
Zimbabwe	28	0.8	77	480

Source: G. FOLEY, *Outside the oil economy - rural energy in developing countries* (1984).

TABLE 4 — *Expected Commercial Energy Consumption and Imports in the Oil Importing Developing Countries.*

	Consumption			Imports		
	1980 Million toe	1995 Million toe	1980-95 percent growth per year	1980 Million toe	1995 Million toe	1980-95 percent growth per year
Oil	360	531	2.6	295	386	1.8
Coal	186	442	5.9	—6	58	—
Natural Gas	26	120	10.7	—1	5	—
Primary Electricity	98	306	7.9	0	0	0
TOTAL	670	1399	5.0	288	449	3.0

Source: The Energy Transition in Developing Countries, The World Bank, Washington DC, August 1983, Chapter 1.

it differs in essence from other forms of supply. Energy supply projects are large-scale and susceptible of individual assessment. A new power station can be assessed in this way, and when it comes on stream (hopefully on time and on cost) will produce (hopefully) a certain quantity of power. Conservation decisions are fragmented — they depend for the most part on the individual decisions of a myriad of consumers at home and at work. Nevertheless the World Bank has estimated that a major conservation effort could yield at least as much energy benefit — 1.2 mbd of oil equivalent by 1990, saving import costs of US $ 18 billion (at 1980 prices) — as a maximum effort to exploit indigenous oil reserves. An effective conservation programme includes both more efficient management and a shift from high-cost energy sources to cheaper forms of energy.

Improved Energy Efficiency

No matter how advanced an economy there are always economic opportunities for improving the efficiency of energy usage. The six main sectors in developing countries are the domestic, agricultural, industrial and transport sectors, commercial and institutional building, and the energy supplying industries.

The *domestic sector* accounts for about 45% of total energy use in the developing world, but only 10-20% of their commercial energy consumption. In low income countries these shares are 75% and 10% respectively. But within all these economies is the urban/rural divide. In the urban sector, commercial energy is used for cooking, refrigeration, lighting and in the range of services employed; in the rural areas, (containing 2½ billion population) domestic fuel is obtained, free of payment, from forests or agricultural waste. This usage is alarmingly inefficient. Many studies of wood usage have been conducted, some showing a consumption of over 2 tons per head per year. (1) By comparison with industrial countries, this is extraordinarily high. It has been estimated that for a family of six, it is an annual consumption of 72 GJ; the consumption for cooking in an average UK family is 5.9 GJ. (2) In other words, the average wood using family in a poor developing country may be using 12 times as much energy for cooking as an ordinary UK household.

This wasteful usage is reflected in destruction of the environment. Deforestation means people having to go much further in search of fuel. Dung which could be used as fertiliser yields only domestic ash. The creation of a commercial market in fuel wood which is an increasing feature of urbanisation exacerbates these problems. Moreover, in addition to the hardship imposed on the rural poor as fuel wood supplies become scarcer or are diverted to commercial markets, it has been estimated that without significant re-afforestation programmes accessible forest cover will disappear in most of the low income African and Asian OIDCs within the next two to three decades — there will be other undesirable effects including topsoil erosion, declining agricultural productivity, a growth of deserts, reservoir siltation and reduced retention of water in catchment areas.

To bring these individually garnered resources under communal control and create an adequate replenishment programme will require a vast and imaginative effort. The promotion of higher efficiency of wood stoves and fuel-switching are not easy in a Third World that has seen many failed schemes to promote alternative energy and cannot afford kerosene or the electricity supplies that pass their doors. There is a reluctance to move from traditional open fires which provide ancillary benefits (e.g., space heating, lighting or protection against insects). Never-

(1) Barnard G.W. and Hall D.O., *Biomass for developing countries* (1981).
(2) Leach G. et al., *A low energy strategy for the UK* (1979).

theless, the pressure to continue to improve stove-design and facilitate their introduction has to he maintained, with an increased focus on urban wood users who have a financial spur to take action.

Agriculture accounts for a relatively small proportion of commercial energy consumption — usually in the region of 5%. However, rising energy prices have a very adverse effect on the costs of production and the rate of technological innovations that depend on comhinations of improved varieties, assured irrigation and the application of petroleum based fertilisers and herbicides.

It has been estimated that in the next two decades nearly three-quarters of all increases in the output of basic staples will have to come from yield increases, so the energy demand will have to be carefully managed to sustain technological change. Wasteful uses of energy must be ended, e.g., subsidies for high cost mechanisation or petroleum fuelled pumping stations. Farm practices also need to be improved. It is estimated that only 30% of the plant nutrient in chemical fertilisers applied in developing countries is used by the plants and the rest is wasted — so are vast quantities of irrigation water. The scope for improvement is so great that a substantial increase in production could be achieved by the vigorous application of existing technology. Further research on new approaches like biological nitrogen fixation and solar pumps for irrigation should be pursued urgently. Lastly, countries with their own petroleum resources (e.g., India, Egypt) might well consider whether some part might be deployed to greater overall advantage in the rural sector than in earning foreign exchange.

Industry is a major user of commercial energy in the developing world. Countries with a high level of energy consumption are also major producers of the more energy intensive industrial products. Half of the total commercial energy consumption of developing countries is absorbed by iron and steel, cement, pulp, and paper, chemicals, fertilisers and petroleum refining. The potential for increased efficiency is shown at Table 5. Experience in the industrialised countries has shown that energy costs per unit of output can be substantially reduced through a variety of measures, ranging from "good housekeeping", energy management, improved monitoring and control systems to more capital intensive investment in retro-fitting existing equipment and using more energy efficient processes. The pay-back periods are relatively short — even in the case of large investments it is usually under five years, with economic returns of 17 to 50 per cent. The potential for energy savings in other industries is also

TABLE 5 — *Potential Energy Savings in Selected Industries in Developing Countries.*

Industry	Total developing countries commercial energy consumption (million toe per year)	Potential savings (percent) Category A	Category B
Iron & Steel	109	3	15-20
Petroleum Refining	54	7	15-25
Cement	52	11	18-28
Chemicals (Ammonia)	19	2	20-25
Pulp and Paper	15	11	12-15
Aluminum	13	2	10-15

Note: Category A refers to small investments consisting mostly of combustion efficiency improvements, insulation, steam system efficiency improvements, and other housekeeping measures; paybacks within 10 to 20 months.

Category B refers to large investments in retro-fitting existing plants and additions to facilities, including waste heat recovery, combined heat and power generation, increased use of waste fuels, simple process changes and controls, and replacement of inefficient equipment; payback in 2 to 5 years. Savings in categories A and B are not necessarily additive in specific plants.

Source: World Bank: Energy Transition in Developing Countries.

substantial, but more fragmented since energy is a much smaller proportion of total costs. But the same technologies are relevant and pay-back periods equally short.

Even with existing technology alone impressive savings can be made. Audits of energy use are essential to enable realistic targets to be set for improved energy usage. Then priorities can be set for the adoption of such technologies as waste heat recovery, improved instrumentation and control, cogeneration and the utilisation of waste as a fuel. Advanced technology can produce even greater savings, coupled with major changes in industrial process systems to adjust to higher cost energy. And continuing and responsible energy management will ensure the maintenance of improved energy performance.

Much of the *transport* system in the developing world depends on human or animal power. However, the modern transport system relies almost exclusively on petroleum fuels and accounts for 20-40% of petroleum consumption. The vast majority is used by road vehicles, predominantly trucks. Since there are only limited opportunities for fuel substitution, it is important to encourage the maximum usage of mass-transport systems. Greater efficiency in the road fleet can be obtained by better training of drivers, better vehicle maintenance and better route planning. Traffic management in urban centres can also make a contrihution. Automobiles typically consume two or three times more energy per passenger-kilometer than buses or railways, at reasonable levels of utilisation, and truck transport three to ten times more energy per ton-kilometer than rail freight, pipelines or maritime transport.

The *commercial and institutional buildings* sector is becoming an increasingly important user of energy in the middle income developing countries and in some small countries where air conditioning — particularly of hotels for tourists — accounts for a significant proportion of electricity demand. In these situations, the scope for energy savings may be sizeable. In existing buildings, savings of up to 25 per cent can be achieved through better energy management, improved control and monitoring systems, and minor retro-fitting investment. Improved standards and regulations for the design of new buildings can reduce their heating and cooling requirements to 50 per cent of those of buildings designed as recently as ten years ago. In some countries, solar collectors can economically displace conventional fuels for heating water in hotels and other institutional buildings. Substantial advances have been made in these areas in industrialized countries and a variety of new techniques, equipment, and materials have been developed. Governments can help in this regard by providing information on new designs to the local architectural community, by revising the codes and regulations governing new buildings, building equipment and materials, and by stimulating audit programs and the production or import of energy management technology and know-how for the building sector.

Another major source of saving is in *energy distribution and supply.* Table 6 shows the losses experienced in electricity transmission and distribution systems in 76 developing countries. It has heen estimated that the typical power system in developing countries needs to reduce its losses by one-third to one-half. Investment in loss-reduction facilities is necessary — it can be nearly three times cheaper to save 1 kw of electricity by this means than to provide similar new generating capacity. Generating efficiency can also be raised by improved energy management. Cogeneration has a part to play. Furthermore, conservation at the end-use stage may be achieved by two principal methods: improving the

TABLE 6 — *Electric Power Lost in Transmission and Distribution Systems in Developing Countries, 1980.*

Losses as percentage of generation (i)	Percentage of countries (ii)
0-10	17
11-15	33
16-20	21
21-30	21
31-40	8

(i) Includes technical losses and unmetered consumption.
(ii) Sample of 76 developing countries.
Source: World Bank.

technical efficiency of energy using devices and appliances and changing the shape and characteristics of the load through load management techniques. Loss reduction in petroleum refinery operations as well as distribution and retailing activity are areas in which significant gains could be made. Production of charcoal has also a significant potential.

Barriers to Conservation

With this high potential for increased efficiency, it is perhaps surprising that conservation policies have not been more vigorously pursued. Obviously, economic pricing of energy is central to an effective conservation policy. Energy prices must reflect the workings of the market and so give energy consumers the correct signals for the future so that they can adjust their practices and investment decisions accordingly.

But other obstacles weaken the pricing message. Some of the main barriers are:

(a) A low priority for conservation, at governmental and management levels. Decisions on energy use and conservation are not seen as major factors in strategic objectives and are therefore accorded low priority in the allocation of resources, both managerial and financial. Major supply investment is often preferred.

(b) Uncertainty, both over the future level and pace of change of fuel prices and over the economic future generally.

(c) A lack of appreciation of the scope for increased efficiency and of what can be achieved technically.

(d) Technical risks and uncertainties, particularly where new technology is involved (though in the vast majority of cases the technology is available). It is sometimes feared that conservation measures will not yield the predicted savings, or that they may cause more frequent disruption of production.

(e) The fragmented nature of the conservation equipment industry. Its products are dispersed throughout a wide variety of different industries and it is not yet sufficiently geared to marketing conservation systems or energy efficient packages and providing follow-up services.

(f) Lack of capable government organisation.

There is therefore a major role for government to play in devising and implementing sectoral programmes for increasing energy efficiency. This is even more important for those developing countries that have not felt able to adopt economic pricing of energy.

A Governmental Programme

The UK experience in developing a conservation programme might be helpful in suggesting the role that government could play. The main elements of the UK programme which is administered by the Energy Efficiency Office of the Department of Energy:

(a) a strong information and publicity campaign, directed at all sectors of the economy;

(b) a vigorous programme for energy conservation in the public sector, including government buildings, hospitals, schools, local authority buildings, and public sector housing;

(c) new building regulations to improve insulation standards and heating controls;

(d) the promotion of the role of energy managers in industry, commerce, government and the public sector and appropriate training programmes;

(e) a range of information and advice services to industry including the identification of conservation potential in individual industries, assistance for individual consultancy advice by experts, encouragement of monitoring and targetting schemes in individual sectors and an energy efficiency office appointed by Government in each of the main regions of the country;

(f) support for energy saving demonstration projects in all areas of energy use;

(g) encouragement of co-generation;

(h) discussion with the motor industry on improved vehicle and fuel economy;

(i) an information and publicity campaign aimed at the private motorist;

(j) a grants scheme for the insulation of privately owned dwellings (more recently extended to cover public sector tenants);

(k) a grants scheme to industry for the replacement of boiler plant, installation or improvement of insulation, and improvement of combined heat and power systems;

(l) a grants system for switching boilers from oil and gas to coal;

(m) a mandatory car fuel consumption testing and labelling scheme under which all advertising which mentions fuel consumption must be based on the results of an officially approved test result, a full list of which must be available in new car showrooms;

(n) energy education in schools and a study of available training in tertiary education to ensure that the requirements of industry are being met by the education structure.

But any programme, however carefully devised, is only as strong as the political commitment behind it, the setting up of appropriate institutional arrangements, the allocation of the necessary resources of man-power and finance.

The institutional framework will obviously vary from country to country. In some countries it can be run from an existing government department, in others a special energy conservation department or independent agency may be deemed necessary. But it is important to emphasize the inherent inter-relationship between energy planning and management policies and overall economic policy. Energy conservation is not an end in itself — it is to improve the use of energy resources so that the main objectives of the nation — whether in economic development, social services or improving the quality of life — are achieved more efficiently. Consequently, an effective energy management programme needs to be fully integrated with the national decision-making process.

Role of International Institutions

The World Bank is, of course, by far the largest source of public support for energy development in the developing world — in some sectors virtually the only agency providing both technical advice and financial assistance. Since the role of energy conservation has become increasingly apparent, the World Bank has undertaken an impressive series of Energy Assessment Studies in the developing world and supported the introduction of energy conservation programmes and investment in individual countries. Moreover, existing guidelines are being adapted to the special pattern of the needs now being identified. The U.N. has recently produced a major inter-agency study of the economies of conservation and substitution. And regional agencies such as OLADE are promoting in-depth assessments of the potential conservation within these areas.

With the enormous debt burden of the developing countries, finance may retard the development of appropriate programmes. The burden of financing energy imports has increased sharply. The change in the proportion of merchandise exports needed to pay for energy imports between 1960 and 1976 has been quite dramatic — it rose from 11 to 26% for India, from 21 to 43% for Brazil, and from 16 to 58% for Turkey. Looking ahead, for the OIDCs as a whole, the World Bank has estimated that almost $ 900 billion (constant 1982 dollars) will be required for energy needs over the next decade, with one third coming from international sources and the remaining two thirds from domestic sources. Still further international co-operation and assistance is likely to be needed.

Conclusions

Energy conservation has a vital role to play in the developing world. Dependence on diminishing sources of non-commercial fuels, the high cost of commercial fuels, the heavy burden of international debt and the high cost of new energy supply projects will all combine to retard the pace of economic development. In the short to medium term the principal contribution to adjustment to the energy crisis can only come from improved efficiency in energy supply and use.

Conservation is not a question of deprivation or sacrifice. It is essentially improving the efficiency of resource usage to further the economic and social objectives of each country. It is in effect a resource that can be brought on stream rapidly, at relatively low cost and with existing technology.

The potential for conservation in the developing world is very high — especially in the OIDCs. Why is progress so slow? Economic pricing of energy is vital — but not all developing countries feel able to pursue it. And there are major barriers to be overcome — lack of knowledge of the problems and technical solutions, lack of a proper institutional framework to initiate and implement conservation programmes, shortage of capital and so forth. Unfortunately, few developing countries appear to have tackled these problems with determination and resources, and a much higher priority needs to be given in most developing countries to improving energy demand management and developing the necessary institutional framework and instruments of policy.

The World Bank has played a major role in focussing attention on this area through the UNDP/World Bank/Energy Assessment Programme, and its lending and assistance programmes also reflect this priority. The technology is available and the experience of the developed world can also be harnessed.

Political commitment is of the essence. And time is running out. Every energy shock increases the fragility of developing regimes. The recent weaknesses in the energy market should not induce a false sense of security. Energy conservation is the seedcore of the future.

DISCUSSION

MALU

Prof. Blanc-Lapierre, what I think is an acceptable strategy for energy development should include the following steps:

a) projection of basic needs and of economic development;

b) find energy requirements for basic needs;

c) provide the necessary energy at tbe lowest cost;

d) for needs above basic ones apply marginal cost pricing policy.

A study that I have carried out showed that the actual average consumption of one cubic meter wood fuel is sufficient to guarantee the minimum needs for cooking, lighting, transportation.

I have a remark for Mr. Couture. From Zairian experience it appears that in defining an energy strategy, the demand side is perhaps more important than the supply side. Three are the aspects which have to be taken into account: how to assess energy demand; how to create a market for the energy which will be produced; and how to define the right price for energy so that it will be remunerative and attractive.

Mr. Frisch, personally I have some doubts about the usefulness of following a global approach. One is induced, in looking at the problem on such a big scale, to have a fatalistic approach, that is extrapolating well into the future basic historical tendencies. I am more and more convinced that one must put a bigger emphasis on what I call the teleological approach, that is, a goal oriented approach. Unfortunately there does not exist a recognized working model. The world economy changes, the emergence of new political, ethical and social values, in part justifies this need for a new approach.

It is my opinion that the underlying assumption that the South will follow the same development model of the North is not sustainable.

Finally, the exercise that you have presented is based on a strong correlation of energy and economic development as measured by the GNP, but this is a correlation which becomes increasingly weaker.

FRISCH

The work I have presented here is not based on a global approach in the classical sense. We gave a very high priority to the decentralized opinions and information. Each region was free to choose its own methodology to forecast its own future.

Speaking about the GNP, its figures were taken in an ex-post approach and were not entered as an input into the model.

COLOMBO

You said that your energy demand projection did not take into account any GNP projections and that GNP projections have been obtained ex-post.

I do not really understand how one could project the demand of energy without any assumption on the development of the economy and how one could harmonize the development of the economy within the different regions. Really, I am a little bit lost.

FRISCH

We did not want to impose GNP energy assumptions as an input coming from the central team. Some regions have worked with models which used GNP input, some did not. The coherence of all these different approaches was assured ex-post. We discussed with the different teams if it was possible to relate GNP background information with projection of energy consumption.

Let me repeat that we did not use a centralized global model in which GNP is a main input.

COUTURE

I am grateful to Dr. Malu for having stressed a point of great importance in my presentation, that is, the problem of assessing energy demand over that concerning energy production.

A possible way to cope with the difficulties of projecting energy demand is the recourse to an interactive methodology which, going back and forth, from the hypothesis to the results for several times, allows you to adjust the hypothesis that you made to an acceptable result.

The two conditions for energy price that you mentioned before, that the price is to be remunerative for the producer and attractive for the user, highlight the problem, very often present in LDC's, of the necessity to reconcile what is desirable with what is possible. Sometimes you have to make sacrifices on one, or the other, or both parts of the problem. You cannot get out of the constraints which are imposed by the external economic environment.

You have to have some special consideration for the need of the poorest part of the population and you have to depart from free price policy in some limited cases.

GOLDEMBERG

Miss Carter, thank you for your wonderful presentation.

Not many years ago economists were lecturing us on the linear correlation between economic growth and energy consumption and the supply side was dominant in their considerations. Now we have economists who express an opposite view and stress the importance of energy conservation.

I have a question to Mr. Frisch. Given the fact that all over the world the people you talk to have access to the same information on what industrialized countries do, how different were their methodologies? And how much guessing did you put into your projection in linking energy consumption to GNP?

It seems to me that the point that Miss Carter made on energy conservation is a very important one; did you take it into account?

FRISCH

Yes, energy conservation was one of the factors that each region took into account. The World Energy Conference is putting a large effort in energy conservation activities in the LDCs. There is a special Committee which tackles this problem, and we are conducting many studies on this topic.

SUAREZ

Mr. Malu's remarks on the need of a goal-based approach, the "teleological approach", pleased me very much. I agree that we cannot simply extrapolate the past. It seems to me that in order to do that we need not so much a model but a very analytical methodology, departing not from demand, but from needs.

We have to know how to create a market. Energy is not a primary problem when one has to give the people an income in order that they have the opportunity to buy something.

In relation with the global study that Dr. Frisch presented us, even if it has been done in a decentralized way, it seems to me that it has the kind of fatalistic approach that Dr. Malu criticized. I think that we have to share the point of view expressed by Prof. Blanc-Lapierre and by Prof. Colombo.

Coming to Miss Carter's presentation, I agree that conservation is important, but one cannot act only through prices, and I insist on the importance of technical assistance and financial help. Miss Carter referred to electrical losses. It is true that they exist but not all of them are real losses. A certain amount is electricity consumed and not paid for, because people do not have the money to pay for it.

SMITH

I think Miss Carter's presentation summarizes the basic lesson we learned since 1974, that there is not an iron link between energy and GNP, a very fortunate lesson for us. There has been more thinking about conservation as an energy source, there has been much more contribution from this source than all the other ones put together since 1974.

I just want to make a small comment on an item that two speakers mentioned, that is the efficiency of small stoves burning biostocks. Figures of 25% were mentioned. Actually, efficiency is an improper term to use for the tests which were performed. People doing such tests avoid the word efficiency. They use the term: heating utilization. Basically it is very difficult to define an efficiency for a device which can be used in so many different ways even by the same person at two different times.

ENERGY REQUIREMENTS OF DEVELOPING COUNTRIES: THE VIEWPOINT FROM INDIA

GOVIND KUMAR MENON
Planning Commission, Government of India

Any meaningful discussion on energy will have to take note of the increasing population. The world population has been increasing at an alarming rate and has been causing great concern. To provide food for this population it will be necessary to use a large proportion of the agriculturally acceptable land for the production of food crops, leaving only marginal areas for energy cultivation. The alarming rate in the growth of population has been a worldwide phenomenon. As can be seen from the table below, the population of the world was 1 billion in the year 1800. It doubled to 2 billions by 1925 and to 4 billions by 1975. It is expected to be around 6 billions at the end of the century and 8 billions by 2025.

The world population would perhaps saturate around 10 billions.

World Population

1800	1 b
1925	2 b
1975	4 b
2000	6 b
2025	8 b
Saturate	10 b?

While there is growing realisation of the need to control this increasing population, and efforts to check this are under way, any success which we will achieve will only be a slow process. This situation therefore represents a unique period of pressure.

The Indian energy scene is characterised by very low per capita energy consumption. The table below illustrates the energy consumption (KGCE per capita).

Energy (KGCE) Consumption per capita

India	190
South	500
North	5700
N. America	11000

The developing countries taken together (South) have a very low per capita consumption of commercial energy, namely 500 KGCE; (out of this the per capita consumption for India is as low as 190 KGCE.) This has to be compared with a figure for the affluent North, namely 5700 KGCE which is a factor of 12; and as high a figure as 11000 KGCE for North America. The essential point to remember is, therefore, the need to increase rapidly the per capita energy in developing countries. In regard to India, we have to cater to the existing population of about 700 million which is growing at the rate of 2% per annum. The population in India was 684 million in 1981. It is expected to grow to 1000 million by 2001 and by 2031 this would come to about 1375 million. It is well recognised that there is a direct relationship between per capita energy consumption and the standard of living or per capita national income. At a low level of energy consumption, development cannot take place to the desired level. Hence in any plan for development, energy assumes great importance, and appropriate emphasis should be made in energy planning in national development. In this context I would like to quote from Dr. Homi Bhabha. He said, "No power is as expensive as no power".

In Indian planning, energy has always received priority attention. *Up to* 1980 investments in energy have been of the order of Rs 15893 crores (*) as against investments in all the sectors corresponding to a figure of Rs 84,451 — this is about 19% of the total allocation. In the 6th 5 Year Plan, the power sector alone, the investment has been Rs 19265 crores against the total public sector allocation of Rs 97500 crores, which

(*) Rs 1 crore ≈ $ (US) 1 million.

comes to about 20%. The total investment in the 6th Plan for energy including coal and oil comes to Rs 26535 crores out of the total allocation of Rs 97500 crores. This comes to about 27%. The table below indicates these facts.

Sixth Plan

1980-1985: Outlay (Public Sector)

El. Power	19265
Oil	4300
Coal	2870
New	100
	26535
	i. e., 27% of
Total Plan	97500

It is to be recognised that if investments in energy are not made at the desired level and sufficient energy produced, investments down-stream would only remain unproductive.

An important characteristic of the Indian population is the significantly large rural population, which constitutes 76% of the total. The basic source of energy of the rural population consists of non-commercial energy (fuel, cow dung and agricultural residues). In India, commercial energy is consumed predominantly by the productive sectors of the economy. In overall terms, the household sector is the largest consumer for energy, accounting for 50% total energy consumption. However, most of the energy used for this sector is derived from non-commercial energy sources, the share of commercial energy in this sector at present being 5%. The non-commercial energy consumption has been steadily decreasing as can be seen from the table below.

	% Commercial	% Non-commercial
1953	32%	68%
1965	48%	52%
1975	56%	44%
1980	58%	42%

From 68% in 1953, the percentage of non-commercial energy has dropped down to 42% in 1980. At the present moment the share of non-commercial form of energy is about 42%. While the percentage in the total share has reduced, in terms of amount consumed there has been a steady increase. In 1953 the amount was 126 mtcr. This increased to a level of 220 mtcr in 1980. Approximately 60% of this is firewood.

Since the production of biomass on an increasing basis for fuel purposes has not yet been achieved, increased consumption of fuel wood has led to destruction of forests, which has been at an alarming rate. This will, therefore, pose dangers from the ecological point of view, and act as a time bomb of deforestation.

Another characterisation of the rural energy scene is that, in spite of the use of oil, the rural scene will continue to be dominated by increased use of draught animal power; and their importance in the rural energy scene cannot be underestimated.

The advantages of the non-commercial form of energy are its availability at a low cost, and on a decentralised basis.

The industrial sector is the largest consumer of commercial energy (about 38%), followed by the transport sector (about 32%). The agricultural sector, which accounts for about 40% of the national income and 70% of employment in the country, accounts for only about 11% commercial energy production. There is a large disparity by a factor of 5 to 10 between the urban and rural areas in the availability of power. Though rural electrification has made considerable progress, the percentage of households electrified is only about 14%, and at present only an estimated five million households use kerosene for cooking. At the same time, about 90% of the households rely on non-commercial forms of energy for cooking. One has also to keep in mind that, apart from availability of commercial energy, there is the question of ability to pay for it, which is a significant factor. It is therefore important to have speedy development of new and renewable energy sources which can be local and at the same time decentralised. There has been recently an increasing thrust on development of new energy sources.

Growth of Commercial Energy

The table below indicates the pattern of growth of commercial energy during the period 1953-79.

Commercial Energy
1953-1979 Growth

Coal	3.7%
Oil	7.9%
Power	10 %
Total	6.7%
GDP	3.5%

The percentage growth for coal is 3.7%, that for oil 7.9% and that for power 10%. The total growth for all the sectors taken together has been 6.7% over this period. This has to be compared with a growth in the GDP rate of 3.7%. The country has had to build up an energy intensive infrastructure and there has been an increasing amount of modernisation leading to a preference and a shift from non-commercial to commercial energies. This has contributed to a shift from the use of non-commercial energy.

As mentioned earlier, the rural economy contributes 40% of the national income, 70% of the jobs, and uses only 10% of commercial energy. In order to meet the energy demands for increased food production over the next fifty years to cater to the increasing population, efforts to increase the availability of energy assumes greater significance. India has been making continuous efforts in this direction. The major effort over the next few decades will have to be through an increase in the production of coal and oil. The growth per annum of energy availability has to be from 7% to 8%. We should aim at increasing the installed generating capacity to about 100-130,000 MW by the year 2000 AD. Nuclear energy will continue to play a key role for bulk energy consumption especially in areas far from coal fields. The target is 10,000 MW by 2000 AD. The importance of nuclear power for the country's development has been recognised several years ago and in this connection I quote from Dr. Homi J. Bhabha: "Moreover, when nuclear energy has been successfully applied for power production, in say a couple of decades from now, India will not have to look abroad for its experts but will find them ready at hand". This was written 18 months before the first atom bomb was dropped on Hiroshima in August 1945, by one sitting in Bangalore, with only the knowledge that nuclear fission had been discovered. It also emphasized Homi Bhabha's philosophy that, by planning and foresight, the country could train its own experts for the tasks of development, to have them ready to undertake these tasks as and when they did arise, and it was important for the nation to find strength within itself rather than develop an attitude of weak-kneed dependence on others — thus emphasizing the need for self-reliance in all fields.

Efforts should also be made in tapping the vast hydel potential and for rapid development of renewable energy sources. Thus, it will be seen that for the Indian conditions it is not a question of developing one particular form of energy but developing all forms of energy and in this an integrated approach is called for.

In the matter of power, an important aspect of the Indian programme has been the achievement of self-reliance in manufacturing equipment for generation, transmission and distribution of electricity. The country has today capabilities for plants up to 500 MW capacity. We should aim at achieving a production target of 5000 MW per year. Indian industry is not only capable of taking care of the requirements for expansion of energy production and supply for the national programme, but they are competing successfully in the international export market.

I have attempted to summarise above the energy scenario for a large developing country, namely India. We have achieved significant progress over the past 30 years. But this has not been without problems. The success so far achieved indicates how we could largely overcome these problems. There have been problems associated with the development of various kinds of energy — problems relating to finance, management, training of manpower, etc.

If we have to achieve a higher per capita consumption the magnitude of investment required is quite large.

I quote here from the speech of the Prime Minister (Mrs. Indira Gandhi, Sept. 1983) made at the inaugural session of the World Energy Conference: "All known strategies of development and of raising the living standards of the poor are energy-intensive. So long as they are dependent on centralized energy systems, people's needs are not likely to be met in full measure. Decentralized systems are necessary to promote regional self-reliance and help the further utilization of materials such as the animal and plant wastes which are available in villages. Such processes could be managed and maintained even by those who do not have much education. I cannot understand why rural problems do not interest scientists and technologists. What can be more satisfying and exciting than ameliorating the condition of millions?. This is one of my constant refrains. We want technology which will reduce drudgery and improve output without displacing the labour technology that will use locally available materials. So far the entire approach in technology has been based on cheap and abundant energy. There should be rethinking on all processes in chemical, metallurgical and similar energy-consuming industries. Whole new areas of technologies are to be developed. The long-range energy problem is far more acute than we think. The world's complacency is totally unjustified".

In spite of our achievement so far, we are conscious of the fact that a lot more needs to be done and there is no room for complacency. All-out efforts have to be made towards achieving a significant increase in the per capita consumption of energy which alone will improve the standard of living of the people. In this we have to have an integrated approach with more emphasis on developing the various forms of renewable energy sources.

ENERGY FOR DEVELOPMENT

JOSÉ GOLDEMBERG
CESP - Energy Company of the State of São Paulo
Brazil, S.A.

It is impossible to understand the energy problems of less developed countries (LDC's) without realizing that they are in reality "dual societies" with an "elite" surrounded by a "sea of poverty".

The *elite* has basically the same consumption patterns in the best districts of all developing countries from Jakarta (Indonesia), Nairobi (Kenya) or São Paulo (Brazil), driving their modern automobiles, living in spacious air-conditioned houses and benefiting from the imported modern technology to which only the "elite" has access. Generally speaking, petroleum is the main fuel on which depends the comfort of "elites" around the world.

The *poor* in less developed countries use primitive technologies, based in general on local fuels, mainly biomass (fuelwood, charcoal, dung and agricultural residues). Most of the "poor" crave for the consumption patterns and comforts of modern civilization which are spread through radio and TV.

The nature of the energy problem in a developing country depends very much on whether one concentrates one's attention on the "elite" or on the "poor".

As an example we will analyze the energy problems of Brazil, a large LDC with a population of 120 million with a tropical climate.

Figure 1a shows the income distribution of this population giving the number of families in different brackets of income (in 1974). Also indicated is the income distribution in the United States normalized to the Brazilian one in such a way that the "rich" (above 10 wage units of income) represent the same fraction of the population in the two countries. The

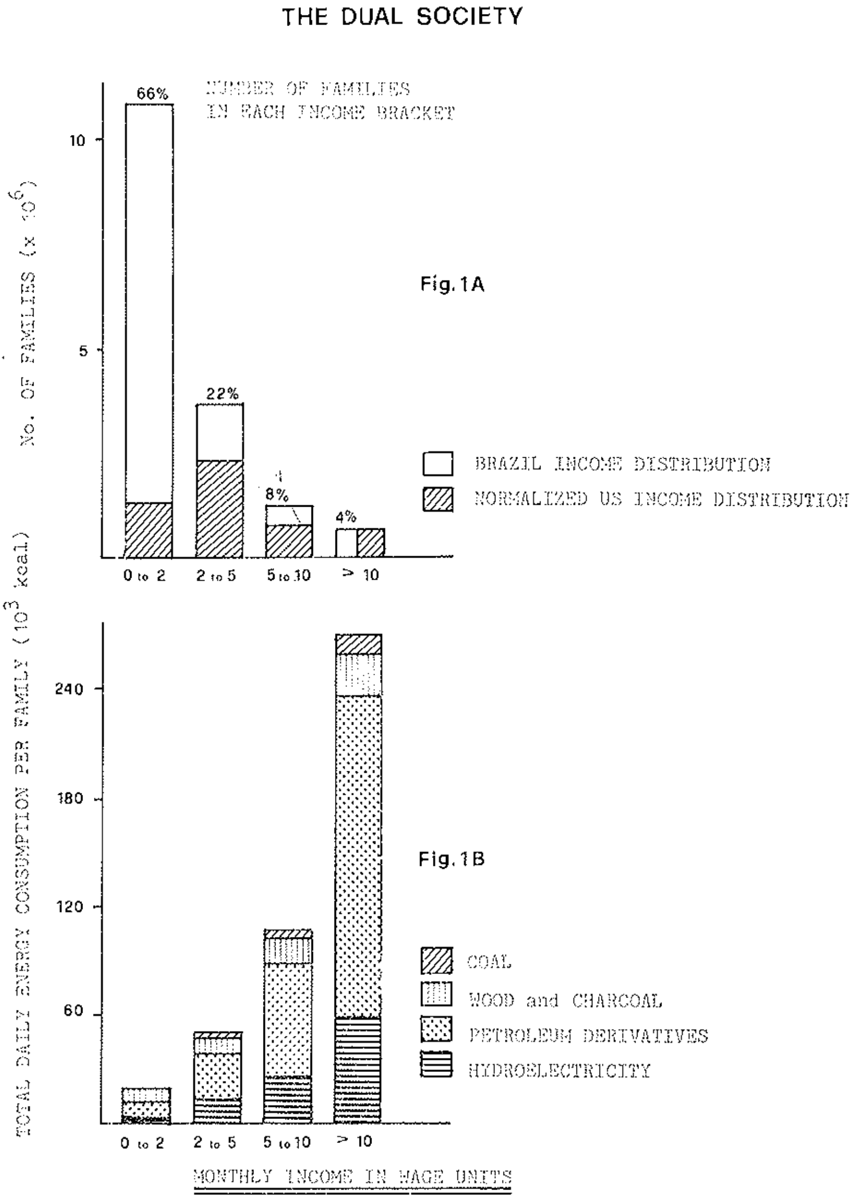


FIG. 1a. Income distribution in Brazil. The US income distribution normalized to the Brazilian one for large incomes is also shown.

FIG. 1b. Energy consumption per type of fuel in each bracket of income.

area in white represents the anomalously large fraction of the population which is "poor".

Figure 1b shows the types of fuel consumed by people in different brackets of income. One can see in this figure the increasing importance of petroleum derivatives (oil) as income increases. This is shown more clearly in Figure 2, which indicates that oil and electricity consumption

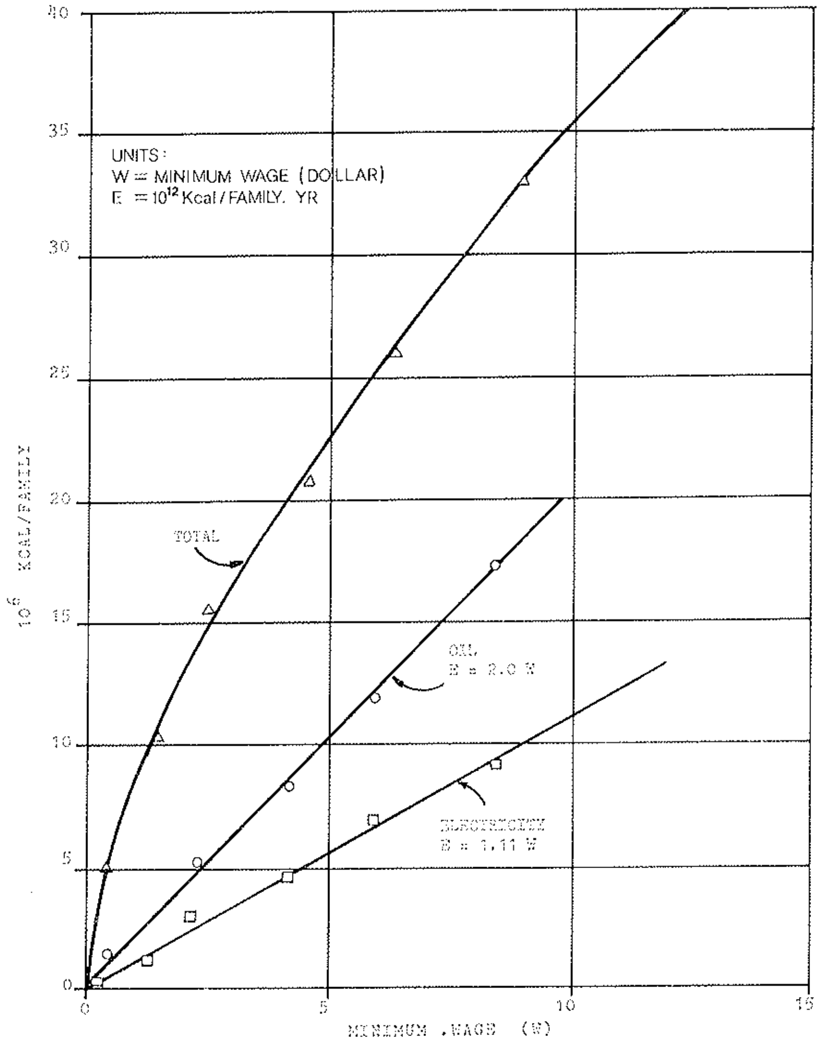


FIG. 2. Total energy oil and electricity consumption for different incomes.

increase *linearly* with income, while total consumption is *not* linear. This linearity is a source of worry because it means that improvements in income have as a consequence greater consumption of oil or electricity.

Figure 3 shows total energy consumption per family in the State of São Paulo as a function of income; large incomes (10 wage units) were considered here, which was not the case in the previous figures since most of the families have income smaller than 10 wage units. It is very interesting to notice the saturation effect apparent in this figure for incomes larger than 20 wage units — "rich families" — which is well known in the developed countries and which results from the fact there is a limit in the amount of domestic gadgets, automobiles and travel that a rich family can have.

The complexity which is apparent in Figures 1, 2 and 3 indicates the amount of information which is lost when one tries to correlate the gross national product (GNP) per capita with per capita income. In such averages the weight of the "rich", who, generally speaking, do not represent more than 10% of the population, is very large. In the case of Brazil 12% of the population (income higher than 5 wage units) consumes approximately 45% of all energy as shown in Figure 4. For this part of the population the energy problem is clearly an oil problem; for the poorer part of the population oil is not so important as can be appreciated in Table I (oil corresponds to 37% for the "poor" but increases to 65% for the "rich").

In Figure 4 direct as well as indirect energy used are included. Indirect energy represents the energy spent in the production of the goods used such as cars or houses.

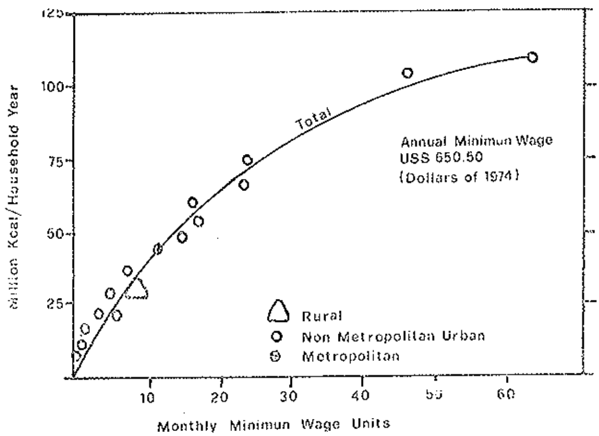


FIG. 3. Energy expenditure for households in São Paulo.

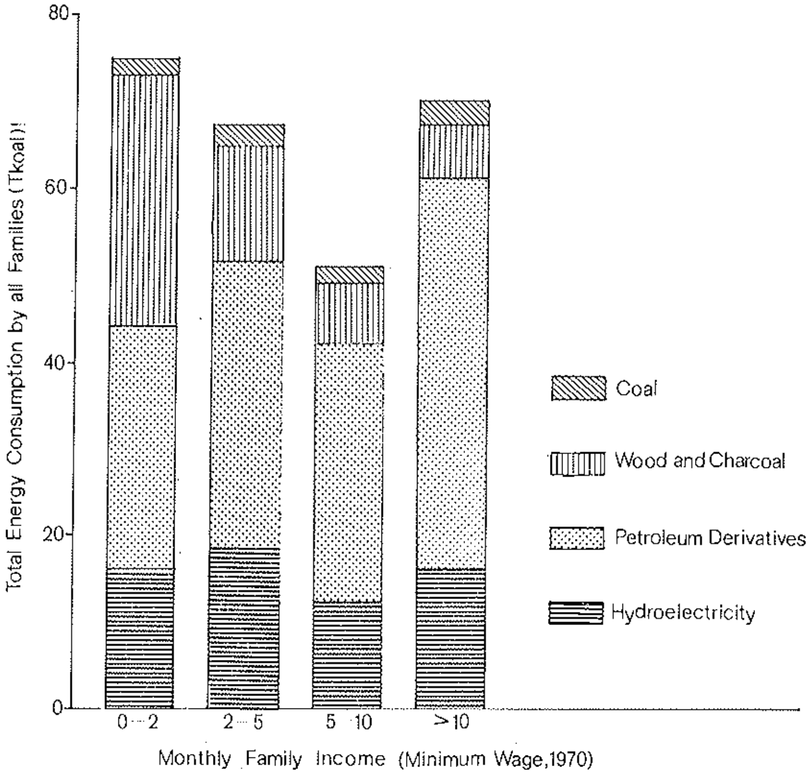


FIG. 4. Total energy spent per year by all families in each income bracket.

TABLE I — *Energy used per type of fuel for different incomes.*

Type of fuel	Fraction of total (%)			
wage units	0-2	2-5	5-10	>10
Coal	2	2	3	4
Wood and Charcoal	39	20	13	9
Petroleum derivatives (oil)	37	50	59	65
Hydroelectricity	22	28	24	23
Total	100	100	100	100

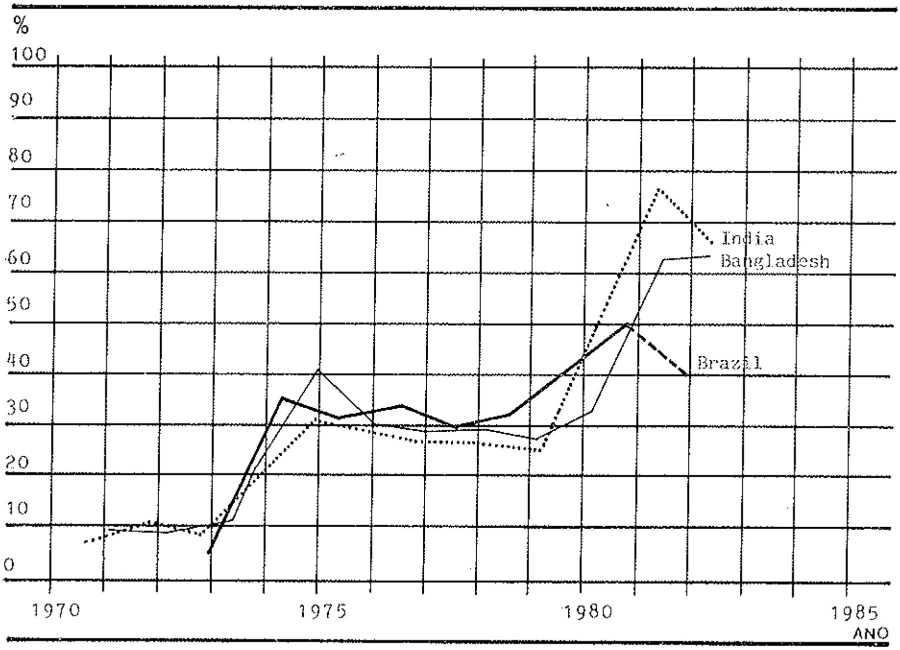


FIG. 5. Petroleum imports as a share of total exports.

The consumption patterns of the "elites" in oil-importing developing countries have led to very serious deficits in trade balances and external debts as can be seen in Figure 5 which shows the amounts spent in petroleum imports as a share of total exports for India, Bangladesh and Brazil.

The seriousness of such deficits has forced many developing countries to reanalyse their energy policies, opening the way for an unexpected convergence of views between the "poor" and the "elites".

The difficulties in importing oil at the levels prior to 1973 threatened the preservation of the consumption pattern of the "elites" while affecting less the "poor". A change of energy policies privileging internally produced energy sources helped both. The production of ethanol from sugar cane in Brazil for example not only led to the substitution of gasoline but also generated more jobs in the production of alcohol as can be seen in Table II and in maintaining in good health the automotive industry.

TABLE II — *The Ethanol Program in Brazil.*

1. Ethanol production (1983)	8.0 Billion Liters
2. Area required (1983)	1.9 Million Hectares
3. Total area for sugar cane (1983)	3.8 Million Hectares
4. Total agricultural area under use (1983)	44.3 Million Hectares
5. Total arable land	100 Million Hectares
6. Target for 1985/1987	10.7/14.3 Billion Liters
7. Automobile fleet (as of December 1983)	10.3 Million
7.1 Gasohol	9.1 Million
7.2 Ethanol	1.2 Million
8. Industrial investment	US$ 10,500/Barrel per Day
9. Cost of production	US$ 0.28/Liter

Figure 6 shows the evolution of the primary energy consumption in Brazil from 1970 to 1985 indicating clearly the decreased dependency on oil derivatives.

This favourable development took place not only due to a change in the fuel mix of the country but also because of a wiser choice of technologies which emphasized energy conservation and self-sufficiency as goals to be achieved. Without such goals the "linearity" discussed before between greater income and oil consumption would aggravate the energy problems of oil importing countries.

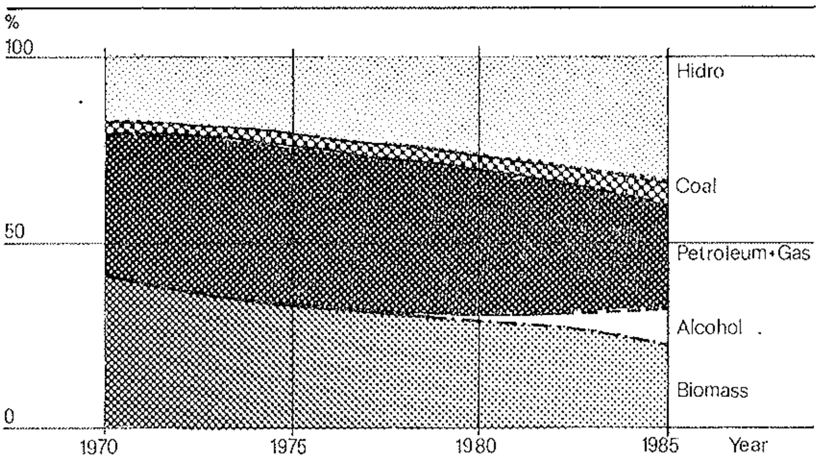


FIG. 6. Profile of energy consumption in Brazil.

For example, fuelwood widely used inefficiently for cooking in the rural areas was replaced by liquefied petroleum gas (LPG) sold in bottles. The steel industry, which used imported coal, was transformed in an industry based on the use of charcoal. This was possible because most new plants used Japanese technology based on charcoal rather than the US coal plants. Presently modern plasma processes based on the use of hydroelectricity (abundant in Brazil) are being introduced.

Another interesting example of a new path for development in the energy area is India, in which the low income fraction of the population depends almost exclusively on dung for cooking and heavily subsidized kerosene for illumination. If large quantities of natural gas, biogas or gas produced from coal were to be introduced in the economy of the country, the efficiency of cooking would be increased dramatically, leaving dung to be returned to the fields as fertilizer, improving agricultural productivity. In addition to that, if electricity were to be used for lighting, subsidies for kerosene presently used as an illuminant, could be removed, which in turn would permit a reorganization of the transportation system. Since kerosene and Diesel oil have comparable prices, most of the goods are transported by truck, discouraging the use of railways, which are a more rational method of long distance transportation.

In such a way the consumption of petroleum derivatives could be reduced; the increased productivity of the fields could be used in part to plant energy forests which in turn could produce methanol for transportation or electricity.

A general formulation of such energy strategy for India is indicated in Figure 7.

Generally speaking, developing countries have an important advantage over developed ones in the sense that all the infrastructure is not in place, so growth can be oriented in better directions than the traditional and inefficient ones.

"Leapfrogging" the industrial countries by the use of new and efficient technologies is a possibility in many developing countries.

Renewable energies are quite abundant in less developed countries and have the possibility of supplying all local needs if properly used. Table III gives estimates of the available renewable energy resources of the world.

There are estimates that a fairly reasonable standard of life can be achieved in tropical countries with an installed power of 1.5 kw which corresponds to an approximate consumption of 30 kcal/capita/day. The

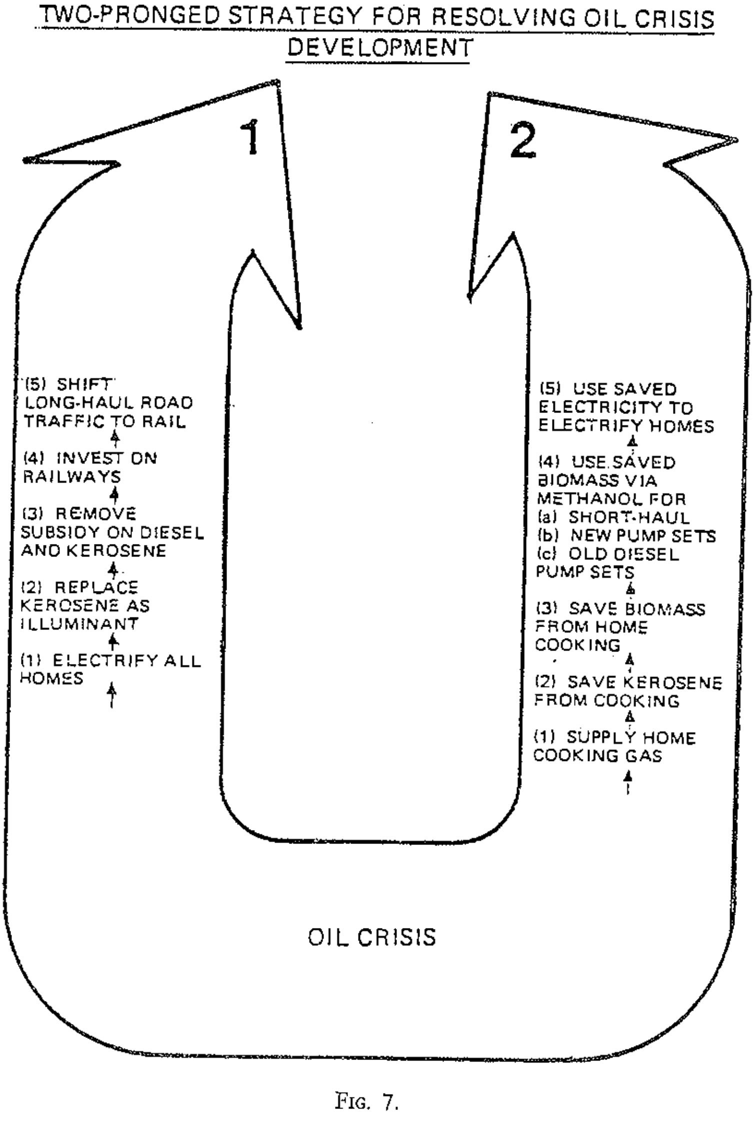

TWO-PRONGED STRATEGY FOR RESOLVING OIL CRISIS
DEVELOPMENT
1
2
(5) SHIFT LONG-HAUL ROAD TRAFFIC TO RAIL
(4) INVEST ON RAILWAYS
(3) REMOVE SUBSIDY ON DIESEL AND KEROSENE
(2) REPLACE KEROSENE AS ILLUMINANT
(1) ELECTRIFY ALL HOMES
(5) USE SAVED ELECTRICITY TO ELECTRIFY HOMES
(4) USE SAVED BIOMASS VIA METHANOL FOR
(a) SHORT-HAUL
(b) NEW PUMP SETS
(c) OLD DIESEL PUMP SETS
(3) SAVE BIOMASS FROM HOME COOKING
(2) SAVE KEROSENE FROM COOKING
(1) SUPPLY HOME COOKING GAS
OIL CRISIS

FIG. 7.

TABLE III — *Renewable Energy Resource Base for the World.*

		TW
1. Biomass Energy from Existing Sources		
Manure and Crop Residues (Taylor)		
Industrialized Nations		0.9
Less Developed Countries		1.1
Unused Increment in Global Forests (Earl)		
Industrialized Nations		2.9
Less Developed Countries		3.2
2. Hydro Resources (Wec)		
Actual Production (1980)		0.2
Energy from Installed and Installable Capacity		1.1
Theoretical Potential		2.9
3. Biomass Energy from 0.5 Billion Hectares of Energy Plantations (*) vs. Yield (Tonnes/Ha/Year)		
	4	1.3
	8	2.5
	12	3.8
	16	5.1
	20	6.3

(*) World Forest Area = 3.8 Billion Hectares.

present world average daily energy consumption per capita in developing countries is 20 kcal. The 50% from 20 to 30 kcal/capita/day may not seem very significant unless accompanied by important improvements in efficiency in energy use.

If this is achieved biomass and hydroelectricity, i.e., renewable energy resources, could supply most of the energy needs of developing countries matching needs to resources.

The more "exotic" — insufficiently tested — technologies that industrial countries are so keenly trying to market in developing countries, such as photovoltaics, solar towers, solar cooling, ocean thermal energy gradient (OTEG), wind towers, etc., have to be submitted to a very critical analysis before being adopted and before a clear understanding of the role they could perform in developing societies.

DISCUSSION

MALU

I thank Dr. Goldemberg for his presentation and his conclusion that there is a need for a teleological approach. But this means we have to concentrate on the general problem of energy management, which includes the efficiency and the conservation aspects. The question is how to use in the best way the limited amount of available resources.

CHAGAS

I want to make three remarks. One, very disturbing, was brought about by Menon, and relates to the fact that many countries are changing their subsistence agriculture for energy purposes. I think that is really an anti-human act. The second point which was already discussed here, presented by Malu, concerns the availability of financial resources. What I want to say has been said many times: three bombers would be enough to pay for the research which is needed to develop and produce the complete vaccine against leprosy. At present huge amounts of money are directed in wrong directions, all around the world.

My third comment is on the very interesting presentation of Goldemberg. In Brazil we have proceeded into alcohol production, and I am convinced it was a very good move, but we are using the worst technologies, with regard to fermentation, biotechnology, genetics, agriculture. We have a very small efficiency in our yield. It is half that reported for the sugar cane production in Cuba. There is much basic research which has still to be carried out, in order not only to produce a better sugar cane, but also to define better fermentation processes. Basic research needs to get more attention from the Brazilian government.

FRISCH

Just two short comments about Mr. Goldemberg's presentation. I quite agree with him when he says that when we are dealing with national energy planning and programming we must be very careful in using analytical tools and to look at the structure of consumption. But I think, on the contrary, we must not, as we say in French, and I hope it is the same expression in English, "throw away the baby with the bath water", and I mean that global approach, and some kind of global approach can be very useful when you are dealing with regional, continental survey, where analytical tools and statistics are not available. That is why I think we must defend some sort of global approach when we are dealing with large aggregates or a large number of countries and this can be used to better understand some evolutions.

But I agree with him that for a national energy planning and for regional energy planning within a nation you have to use an analytical approach.

My second comment will be on the repartition of energy consumption between the different types of household consumption. I guess that the data you have presented refer only to residential uses. If you study the overall energy scene in Brazil, or any other country, you must take into account, of course, industry, transportation and so on. If not, I am afraid that the conclusion can be misleading.

GOLDEMBERG

Allow me a clarification. Total personal consumption is comprehensive of expenditures for transportation, purchase of personal goods, etc. The figures I have shown represent two thirds of total energy consumption in Brazil. They do not include public lighting, for example, but, except for that, everything else is included.

SUÁREZ

I have two comments. One refers to Menon's presentation: I agree with many of his points, but I want to stress that there is a necessity not only to have better financial procedures at the international level but also to have better commercial environments, namely better access to the market and better pricing.

The second remark is related to the capital scarcity and to the problem of interest rates. We agree that this problem exists, but it seems to me that the main point is the one raised by Prof. Chagas, that is the bad use of the existing capital. I want also to say that the main restriction for the development of LDCs is the lack of qualified human resources.

LANDSBERG

I have some supplementary questions to Dr. Goldemberg. How much and which kind of subsidies are going into the adoption of alcohol in Brazil?

I presume that the newer cars as opposed to the older cars are the ones that are fueled by alcohol. From a social point of view, on which you put much stress in the beginning, you are helping those who are in the best position to help themselves at any price, and those who run 15-20 year old cars are not favoured. They may be connected to the subsidies programme.

Third question is the stability of alcohol production, in a sense it does depend on crops, which are notoriously unstable. So may be the market for sugar. What are the mechanisms that are available to assure the users that they in fact have the alcohol, either because the sugar market will go up or the sugar market will go down? Finally, I presume that the investment is based on foreign loans therefore adding to further indebtedness of Brazil, which is one of its major problems, at the moment, in the financial world.

GOLDEMBERG

The programme started with subsidies not for agriculture, but for the construction of industrial plants. These subsidies do not exist any longer.

The new cars are the ones which run on pure alcohol, but all other cars run on a mixture of gasoline and alcohol. So their owners are helped less, but they still are.

The stability of the production of sugar cane and therefore of alcohol, has been discussed over and over again. The sugar cane is spread all over Brazil. It is quite unlikely, given the past experience, that a disease will at the same time affect all the plantations. The cost of sugar is indeed an important consideration. However, people in the position to know about the sugar world market told me that, according to the international trade agreements, it is of no use to produce much sugar because each country has a quota and so there is a mechanism for price stability which will keep it at a low level.

Answering your last question, foreign loans for the alcohol programme have been very small. Only the World Bank has put a given amount of money, not very large, about 5% of the total investment. The rest of the money came from the gasoline tax, which is very high in Brazil. It is not a programme working on foreign loans.

COLOMBO

I want to make just a few comments on Prof. Goldemberg's presentation.

As he remarked, and I want to underline it, the alcohol programme, while certainly suitable to countries that have a large amount of land to grow sugar cane, is not too suitable for countries that have a limited amount of land, which is much more useful to produce food. The second observation relates to the stabilization of the alcohol programme in Brazil. One should not forget that alcohol may be a raw material for new organic chemicals. An entire field of so-called sucro-chemistry, or alcohol chemistry, is being born and indeed I think that basic research in genetics and in chemistry may help generating new products with a very high value added, that will in turn create valuable exportable goods.

It is worth mentioning, because the research needed in Biology, Chemistry, Genetical Engineering and so forth, is directly related not only to the energy problem but also to energy research itself, and this could be one of the important conclusions of our study week.

HUMAN DEVELOPMENT AND ENERGY: A VIEW FROM THE DEVELOPING COUNTRIES

CARLOS E. SUÁREZ, Chemical Engineer
President of the Energy Economics Institute, IDEE,
(associated with the Fundación Bariloche)
San Carlos de Bariloche, Argentina

1. Introduction

When the subject of the relations between the socio-economic-cultural system and the energy system comes under discussion, energy is generally given pride of place and emphasis.

This has become particularly the case in the last decade when energy was a matter of the gravest concern in the international community.

Nevertheless, and in spite of being an energy specialist myself, I would like to alter the traditional approach and stress that our concern should first be directed towards Development of the Human Being, of each and every human being created by God in His own image.

In order to obtain this Integral (and not only economic) Human Development, society must recur to a group of resources among which, it is true, energy occupies a leading place as an instrument of development, though not as an end in itself.

In this short paper, we shall postulate that if socio-economic systems are to function properly, it is necessary to satisfy a set of direct human needs of survival and comfort and indirect needs of production activities which require energy inputs to carry them out.

To satisfy these energy requirements it is essential to define suitable energy supply systems on the basis of local and foreign resources.

Interactions between requirements and provision and between each of them and Nature and Society, make up the energy system whose previous stages must be analyzed in order to make an adequate diagnosis and whose future development must be planned to define the energy policies and implement the necessary projects and construction schemes.

For developing countries the energy problem is intimately linked to their development process and life style and it considerably antedates the so-called energy "crisis" discovered by the developed countries after 1973, and which many would like to see written off as solved, just because there has been a drop in international oil prices.

The main energy problem of the developing countries has for many years been their very low consumption level, measured in net energy; the poor quality of the energy sources used and the low yields of the equipment and appliances, all of which implies a much lower availability of useful energy.

As a result of these exiguous levels of availability of useful energy among the great majority of the population, it is not yet possible at the present time to meet the most elementary needs (food, hygiene, education) or to achieve a minimum level of comfort, nor to carry out productive activities with due technical efficiency — both in rural and urban areas — which would generate a proper income.

This energy problem has been severely aggravated in the last decade by a series of events at international level over which the developing countries have practically no control. Among them, mention could be made of the long-standing tendency for deterioration of terms of trade, the economic crisis of the central economies, the lack of adequate technological transfer and the high real interest rates in the international market, factors which are added to the rise in international oil prices.

We shall now proceed to deal with the above points in more detail.

2. Energy Requirements

In the developing countries it is necessary to regard energy requirements as distinct from energy demand, since the latter embraces only those transactions which have passed through a market, more specifically, a monetary market. However, in these countries there is a large part of the consumption which does not pass through any commercial market and, moreover, unsatisfied requirements exist due to supply restrictions or to the physical or economic impossibility of the consumers to gain access to the necessary and convenient energy sources.

We have already stated that our main objective is to achieve the human development of all a country's inhabitants and for this it is essential to attempt to clearly define what are the total requirements and not just the solvent demand, in order to proceed to study their magnitude and the best way to meet them.

To do this it is necessary to bear very much in mind the particular characteristics of the developing countries.

One of the most important features is the great diversity of situations to be found inside the socio-economic system. Thus we must distinguish between: in the domestic sector, rural and urban areas; different income levels of the population and particularly the marginal sectors; in production sectors, the different production modes which: a) in the rural area range from subsistence systems to modern ones geared to exportation, passing through intermediate commercial systems which supply local requirements; b) in the manufacturing area, they range from craft activities to the great, high-technology industries through a wide gamut of small and medium industries; c) in the transport sector, from the formal organized systems, both public and private, with modern technology of the great urban centers, to the traditional, informal systems based on human and/or animal energy; d) in the services sector, from informal activities carried out individually in the open, to modern services with sophisticated technology.

This wide diversity of situations requires that in the developing countries an analytic type approach be used which, starting out from the end uses, studies the energy requirements of each activity, and not global, aggregated methods which attempt to establish the energy demand through simple econometric models depending solely on the evolution of the GNP and/or prices.

This type of analytical approach allows taking into account the main factors which determine energy requirements, starting from human needs and the level of activity of the production system measured in physical terms.

Thus, for example, in the domestic or residential sector, there is need for nourishment in order to survive and to have suitable production ability, which means preserving, preparing and cooking food, activities that generate a specific energy requirement. To this must be added the energy required to survive in extreme climatic conditions, which is as much a priority as food. We refer both to heating in cold zones and to ventilation and refrigeration in hot zones.

Here it is interesting to make a digression as regards the developing countries. The majority of the population of these countries lives in hot zones and therefore it is often considered that, obviously, heating is not required and that refrigeration is more essential than heating.

This concept amply reveals one of the very many conditioned reflexes created by the technological and cultural influence of the developed countries, where the cold is a fundamental problem. For developing countries, the extreme conditions of heat can lead to death in the same way as cold, while less extreme conditions, but with high temperature and humidity, seriously affect the normal productivity of the human being. It is for this reason that the struggle in these countries against high temperatures should have a similar priority to that given to heating in cold climates.

To continue with the list of needs, we can mention those of hygiene which imply an energy requirement for heating water or for ironing (although it may seem strange, polls carried out in developing countries show the iron to be one of the appliances with most penetration). This appears to be a special cultural pattern which must be respected or a production activity undertaken in the home [1].

There are also the needs of education and recreation which imply an energy requirement for lighting, a problem which in many developing countries has not been suitably solved.

Finally the needs of recreation, information and communication remind us to take into account energy requirements for the appliances related to the mass communications media. In this case also it is important to point out the high priority which even the most marginal sectors (particularly in the urban area) give to the satisfaction of this need, as revealed by the penetrations of appliances such as radios (another of the appliances with great penetration) and television. [1] Tables 1 and 2 show the structure by sources and by uses for different income levels of rural and urban areas in a province with intermediate development in Argentina, [1] as an example of the type of needs present in a particular area and the energy sources used to satisfy them.

This integral postulation may cause surprise in contrast to the many analyses which are limited considering only cooking and the use of firewood, but we consider that if it is not put forward in these terms, the real energy problem of the developing countries, which is the enormous gap existing between present consumptions and the minimum reasonable requirements of the widest sectors of the population, will never become evident (1).

(1) For a more detailed analysis of the subject, see [1] and [2].

TABLE 1 — *Urban Domestic Sector.*

Energy Consumption Structure by Sources and Income Level (%)
Entre Rios Province - Argentina

Energy Source	Income Level	Net L	Net M	Net H	Useful L	Useful M	Useful H
Electricity		15.2	25.3	28.1	25.0	38.7	39.7
LPG in Tubes		7.2	15.7	16.6	9.7	16.7	27.1
LPG in Bottles		34.1	32.0	27.3	45.9	33.9	27.7
Kerosene		18.7	10.1	5.1	14.9	8.8	4.4
Alcohol		0.2	0.1	...	0.2	0.1	...
Firewood		22.2	15.9	11.1	3.7	1.7	0.9
Charcoal		2.0	0.9	1.8	0.4	0.1	0.2
Gasoline		0.1	—	—	...	—	—
Human Energy		0.4	0.1	—	0.1	...	—
	%	100.0	100.0	100.0	100.0	100.0	100.0
TOTAL	koe inhab.	112.0	124.0	163.0	38.7	54.1	74.5

Source: PER Long Term Global Energy Planning, Final Report, Volume 12, C.F.I., Bs. Aires, 1981.
... : Values inferior to 0.05%.
— : Null values.
L = Low; M = Medium; H = High.

In aggregated terms this problematique can also be presented with some figures and graphs.

Tables 3 and 4 give several examples of how energy consumptions are modified as income level of the users increases. In particular, when the useful energy figures which show the real availability at user level are analyzed, remarkable discrepancies can be observed. [3, 4]

Fig. 1 gives a curve which shows the relation between net energy consumption per inhabitant and an index of quality of life, with an indication of the position occupied, by the countries and regions of Latin America. [5]

This graph clearly shows that in the first stage, relatively small increments in availability and consumption of energy produce strong increase in the quality of life of the population, especially when we consider the values in useful energy.

TABLE 2 — *Urban Domestic Sector.*

Energy Consumption Structure by Uses and Income Level (%)
Entre Rios Province - Argentina

Use	Energy / Income Level	Net L	Net M	Net H	Useful L	Useful M	Useful H
Lighting		6.5	5.1	6.4	0.7	0.6	0.7
Cooking		60.5	43.5	40.4	54.2	38.1	32.6
Water Heating		10.8	18.3	25.3	14.0	23.2	29.8
Space Heating		8.8	18.7	13.4	10.1	13.8	11.9
Refrigeration and Airing		1.0	3.3	3.6	2.8	8.4	9.8
Food Preserving		6.8	4.8	4.0	11.2	8.4	7.2
Other Appliances		5.1	6.1	7.0	6.9	7.4	8.1
Water Supply		0.6	0.1	—	0.3	...	—
	%	100.0	100.0	100.0	100.0	100.0	100.0
TOTAL	koe inhab.	112.0	124.0	163.0	38.7	54.1	74.5

Source: PER Long Term Global Energy Planning, Final Report, Volume 12, C.F.I., Bs. Aires, 1981.
... : Values inferior to 0.05%.
— : Null values.
L = Low; M = Medium; H = High.

TABLE 3 — *Domestic Urban Sector, Latin America, Caloric Uses Only.*

(koe/h/year)

Income Level	Hot Zone Net Energy	Hot Zone Useful Energy	Cold Zone Low Income Net Energy	Cold Zone Low Income Useful Energy	Cold Zone High Income Net Energy	Cold Zone High Income Useful Energy
Low	60	23	133	40	230	90
Medium	75	32	166	70	520	234
High	100	38	450	180	920	405
Average		26		56		152

Source: Bariloche Foundation [3].

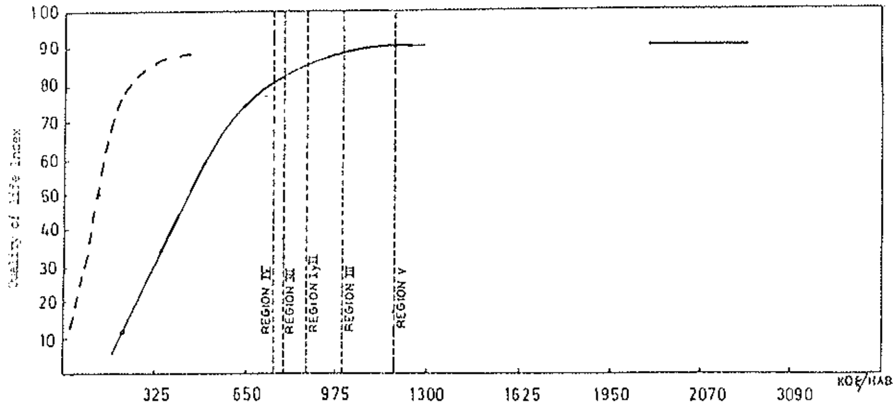
TABLE 4 — *Total Energy Consumption. Mexico City.*
BTU × 10^5/fam/year

Income Level dol/fam/year	Net Energy	Useful Energy
480	186	47
1.700	177	83
3.600	175	90
7.200	263	157
14.400	307	195

Source: G. McGranahan & N. Taylor "Patterns of Urban Household Energy Use in Developing Countries: the Case of Mexico City", IER III, Institute for Energy Research, 1977.

After certain levels, greater consumption does not bring about substantial improvements and if the curve were extrapolated towards very high consumptions, it is probable that quality of life would decrease, as can be appreciated in the great megalopolis-type cities.

The developing countries, and particularly the lowest-income sectors within them, are all in the first part of the curve and it is therefore essential to find solutions for increasing energy availability. Contrariwise, the de-



——— Place of different Latin American countries.
— — — Estimated values in useful energy.

FIG. 1. Quality of life and energy consumption per capita.

veloped countries, and the highest-income sectors of the developing countries are located in those parts of the curve in which greater energy consumption would not improve their quality of life and would even deteriorate it, which reveals the need and advisability of applying to them a strong policy of energy conservation.

This saturation process in energy consumption as income levels rise can also be observed in Fig. 2, extracted from polls carried out in Ethiopia. [6]

This graph too reveals something interesting as regards the subject of population. It shows clearly the inverse ratio which exists between family size and energy consumption per inhabitant for the same income level, which means that the smaller each family, the greater will be the total energy consumption of a system which has a similar number of persons with a given income level. This ratio is also clearly seen in Table 5, corresponding to a province of Argentina, which shows that elasticity of energy consumption per inhabitant in relation to family size is negative. [1] The

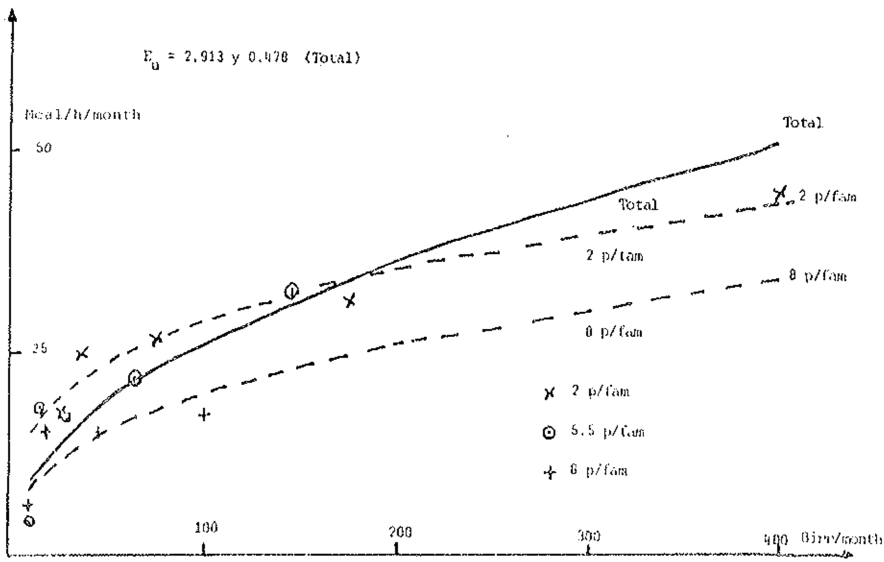


FIG. 2. Useful energy consumption per capita and monthly income per capita. Ethiopia. Urban area.

Source: Energia Domani n. 31-32, CESEN.

TABLE 5 — *Income (α) and Family Size (β) Elasticities in the Domestic Sector.*

Useful Energy

Urban Area	Power		Fuels		Total	
Income	α	β	α	β	α	β
High	0.63*	0.14*	−0.21*	−0.72*	0.24*	−0.27*
Medium	0.27	−0.79	0.38	−0.60	0.68	0.01
Low	1.54	0.21	0.23	−0.49	0.44	−0.44
Total	0.91	−0.24	0.21	−0.59	0.40	−0.45
Rural Area	**Power**		**Fuels**		**Total**	
Income	α	β	α	β	α	β
High	0.82	0.43	0.71	0.59	0.74	0.52
Medium	0.27	−0.58	−0.16	−0.92	−0.06	−0.87
Low	1.09	1.62	−0.07	−0.99	−0.03	−0.94
Total	1.30	0.51	0.06	−0.72	−0.15	−0.65
Province Total	**Power**		**Fuels**		**Total**	
Income	α	β	α	β	α	β
High	0.83	0.13	0.44*	0.44*	0.60	0.33
Medium	0.67	−0.14	0.005	−0.94	0.25	−0.57
Low	1.79	0.81	0.07	−0.65	0.25	−0.62
Total	1.05	0.13	0.13	−0.62	0.30	−0.52

* Values not significant at the 5,0% level.

advocates of population control in developing countries would do well to keep in mind this type of consequence of aggressive policies to achieve small families, since the possible reduction of the population will not generate a proportionate reduction in the consumption of energy and other resources.

In short, to be able to determine energy requirements adequately for the domestic sector of developing countries, it is fundamental to consider explicitly: present and future income distribution, population distribution into rural and urban areas and migratory processes, demographic features which determine family size and population growth, every single human need and not only basic needs. As we can see, to attempt to centralize the explanation of energy consumption in the developing countries in population and income is a reductionist approach which can lead to serious errors of estimation or to ignoring the majority sectors of the population.

The analytical approach [2] attempts to draw attention to the need to study explicitly all the inhabitants of a country and not merely the wealthy sectors of urban areas, as occurs in most cases. This study would then lead to the design of concrete programs and policies to solve the energy problems identified, as we shall see further on.

If we now consider some of the production systems, a great diversity of modes of production for the same activity, product or service can also be distinguished. Each of these production modes is associated with very different energy consumption levels and also structures by uses and by sources of those consumptions, which are substantially modified.

This requires detailed study of which technology is associated with each one of these production modes, taking into account not only specific energy inputs but also other inputs or production factors associated with energy.

Thus, for example, in the agricultural sector special attention should be paid to the use of human and animal energy, to study its possible substitution or to improve its utilization efficiency.

In the case of fertilizers and industrial agrochemicals, consideration should be given to their possible substitution by organic fertilizers (which in addition produce biogas as an energy source) and/or by adequate culture techniques which enable production to be increased without necessarily reducing labor requirements or excessively increasing commercial energy input. The form of supplying water for irrigation and animals also creates specific energy requirements which must be given careful consideration.

For the production modes connected with subsistence systems, it is essential to achieve an effective increase in productivity which without eliminating production for own consumption, would generate surpluses for marketing and give the peasant the capacity for saving and investment necessary to purchase and maintain the equipment and appliances which would allow him to increase his useful energy consumption and improve the quality of the sources used. This, in turn, would allow him to increase even more his productivity and personal quality of life.

Studies connected with the rural area should not be approached as an energy problem exclusively but basically as integrated rural development programs where energy is one more instrument and not an end in itself.

These integrated rural development programs should be regarded as being simultaneously problems of water supply, increased productivity, production marketing, mechanisms, the organization of enterprises, etc.

In referring now to the industrial sector, it is necessary to consider carefully which are the technologies most suitable for the particular conditions of the developed countries and their constellation of natural and energy resources. A typical case is the steel industry which can be approached in competitive terms with technologies such as charcoal-fired blast furnaces or direct reduction with natural gas, combined with the electric steel mill, as alternatives to the classic systems using coal. These technologies, in addition to making use of local energy resources, have lower scale economies which facilitates their adaptation to the size of local markets.

Another important aspect of the industrial sector in developing countries is the fact that agro-industries constitute a very important sector of manufactured products and energy consumption and require a detailed analysis with as much or more priority as the traditional sectors of developed countries, such as steel or petrochemicals.

Many more examples could be given in these and other sectors of the socio-economic system but what must be emphasized here is the need to study the energy problems of the developing countries, starting out from their own real situation, analytically and in detail instead of trying to transplant more or less automatically categories of analysis, technologies and solutions which were developed for very different realities (those of the industrialized countries) with a constellation of different resources as well as different social and cultural patterns.

3. The provision of energy (2)

As regards energy provision, it is also necessary to take the characteristics of the developing countries very much into account.

Among others, we can mention: dispersion of the demand which complicates the provision systems; the problem of the use of insufficiently developed local energy sources; diversity of available systems and technologies; impact of the supply systems upon Nature and the socio-economic system; technological dependence on foreign appliances and on research and development; lack of human resources in sufficient quantity and quality.

As regards dispersion of the demand, it is necessary to study and find concrete solutions not only for the large centralized provision systems

(2) For a detailed analysis of this subject, see [7].

(connected with large urban areas), but also for the local and/or decentralized systems connected with the rural zones where the majority of the population still live.

In this sense it is important to remember the fundamental role which new, renewable energy systems can play in these local and/or decentralized systems, such as minihydros, wind equipment, biogas, solar energy and a rational, adequate use of biomass (firewood, vegetable and animal wastes). Nevertheless, recourse to these local sources should be complemented with the use of conventional sources such as oil derivatives (gas oil, kerosene, liquefied petroleum gas) and electricity, for which the respective distribution systems should be organized under suitable conditions.

In this aspect we have to consider very particularly a very common situation in LDC's when in several heavy producing energy areas (oil, natural gas, hydroelectricity), mainly for exportation, the needs are ignored of the local population that continues to lack an appropriate provision of these same energy sources or has to pay very high prices in spite of being quite near the source of production. Several isolated areas of the Argentinian Patagonia are good examples of this kind of situations. [12]

In connection with the use of energy sources available in a country, it is important to point out that many developing countries possess their own energy resources (biomass, hydroelectricity, coal, hydrocarbons, solar energy, geothermy, uranium) which have often not been developed because they lack the magnitude and/or adequate location according to the international market scale but which from the local viewpoint can be fundamental to increase energy self-sufficiency and to reduce the impact of the energy sector in the country's balance of payments.

Here energy planning, to which we shall refer later, should try to maximize the use of resources originating locally, even if this means a somewhat higher cost for provision from abroad. In many developing countries there are energy resources in suitable amounts for national and/or sub-regional markets, upon which special emphasis should be placed for their development, and concentrating in them activities of international technical and/or financial cooperation.

As regards hydroelectricity (large or small), biomass and solar energy, these local resources also have the advantage of being renewable if properly managed and their use normally originates additional benefits apart from the generation of energy, which are of great importance for achieving the integral development of these countries.

Of course, in development of this kind, repetition of unhappy past experiences must be avoided, where great projects of hydro-electricity or the biomass extraction were not carried out on the basis of local requirements but rather to be intensely exploited for export abroad and having the characteristics of enclaves isolated from the rest of the socio-economic system.

With regard to oil and natural gas, important efforts have been under way in recent years in the developing countries to exploit deposits of local interest and in many cases important successes have been obtained, to which international credit organisms such as the World Bank or the Regional Banks (IDB, ADB, etc.) have contributed. Nevertheless, institutional-type impediments connected with the mechanisms of financing and technological transfer still persist and these should be eliminated through a more positive attitude on the part of multinational corporations, banks and governments of the developed countries.

Finally, we should not forget the nuclear area, in which many developing countries have achieved notable developments in spite of the resistance and obstacles from the developed countries. Nuclear development for exclusively peaceful purposes has fundamental importance for the developing countries, not only for the production of electricity but also for use in medicine, agriculture and other fields of economic activity, not forgetting how much it means to the technological and human development of these countries.

Except for some marginal cases, the developed countries alone are historically responsible for having used and accumulated atomic weapons, reaching absurd limits which place humanity face to face with a permanent risk of its total destruction.

4. Impacts of Energy Development

Just as we said in the previous point that it is the functioning of the socio-economic system which determines energy requirements, so it is the developing and fitting out of the energy system which generates a series of impacts on the system and on Nature.

In particular, we would like to refer to some of these impacts.

4.1 *Land use*

All energy forms throughout their cycle of production, transformation and utilization, require different quantities and qualities of land for the development of their activities and thus this is one of the elements to be considered in defining energy provision.

In this sense, we would like to insist on the subject of the quality of the land necessary and its alternative uses. Lately, energy programs have been proposed based on the biomass and energy plantations which require great quantities of land though with very different qualities. Thus, for example, for sugarcane for the production of alcohol high quality land has been used and its cultivation severely exhausts the soil. In many cases direct competition with food production takes place, thereby posing a very important conflict: to use the land to produce basic food for the great majority of the population, both rural and urban, or to cultivate sugarcane to produce alcohol intended for maintaining the use of the individual automobile in medium and high income urban sectors? Microeconomic and market logic has in some cases led to opting for the latter, when from a social and integral human development viewpoint the former should have been chosen.

Conversely, in other cases, use of the land may not be competitive and may even give secondary benefits. For example, an afforestation scheme will normally use marginal land not suitable for agriculture and will improve soil protection, particularly in the higher parts of hydrographic basins. In other cases, the use of solar panels for hot water or for electricity, can be integrated with land requirements for housing without increasing the total area necessary. Finally the use of agricultural, industrial and urban wastes for energy can free land previously utilized for the disposal of these wastes.

4.2 *Demand for equipment and material*

Every energy scheme requires an important quantity of equipment and material. At present in the developing countries most of it must be imported, upsetting their balance of payments. It is essential to attempt to maximize the use of local materials and to promote the production of equipment with adapted technology and carried out locally in order to stimulate the development of high-productivity economic activities and be a mechanism for increasing national autonomy.

In this sphere, a particular responsibility devolves upon the developed countries which normally attempt to maximize the incorporation of imported materials and equipment into the LDC's instead of facilitating and supporting the development of these activities at local level.

In many developing countries the size of the market is not sufficient for this kind of development and in such cases it is fundamental to build up regional or sub-regional schemes which permit and facilitate a progressive economic integration of these countries.

4.3 *Demand for human resources*

Although it is normally said that the lack of capital is one of the restrictions to energy progress in the developing countries, I believe that, on the contrary, the maximum restriction occurs on the side of the human resources necessary for undertaking sectorial planning, the materialization of investment plans and the proper growth of the energy system.

This lack of adequate human resources occurs at all levels, both in quantity and quality, from the sectors of qualified labor to the highest professional-level directors.

In this field it is also fundamental to modify the present mechanisms of technical assistance, mostly aimed at: "making a present of the fish instead of teaching how to fish".

The quickest possible increase in these human resources is of first priority if the developing countries are to have autonomous decision capacity as regards the solution of their own energy problems, if they are to be capable of making properly balanced negotiations with suppliers and contracting companies and with international credit organisms. [8, 9] Without this adequate human development of their populations, other mechanisms of technical assistance will be of little use.

4.4 *Environmental Impact*

Although this problem would appear to apply more to energy systems of the developed countries, negative impacts on the natural and social environment also occur in the developing countries but in many cases they are of a different kind.

The most serious ones concern the deforestation processes provoked basically by the demand for firewood and charcoal in urban areas in countries where these energy sources predominate ([3]), a demand which

([3]) The latest studies show that the collection of firewood in rural areas does not constitute a basic element in the deforestation process.

overlaps other causes of deforestation not connected with the energy problem (4).

The inundation of vast productive, populated areas for the construction of hydroelectric dams, also means environmental problems.

In coal-producing countries, the inadequate safety regulations in force are responsible for serious accidents with their sequel of deaths and injuries, to which must be added the diseases acquired gradually over the years such as bronchopneumosis and silicosis.

The construction of hydroelectric and other energy schemes also leads to a number of accidents, many of them fatal. The lack of respect for safety regulations in energy production, transport and transformation generates important negative impacts on the natural and social environment.

The negligible spread of nuclear energy in the developing countries until now means that this problem is less tangible than in the developed countries for the time being, but it will increase to the extent that nuclear energy expands in those countries.

In short, it is important to bear in mind that all forms of energy have negative impacts of different kinds on the natural and social environment. What is not always clear is the appraisal of these impacts, depending on who is being affected by them. Thus, for many years thousands of miners or laborers were killed or injured in the different stages of exploitation of conventional energy sources and few voices were raised in protest. Today, however, the potential risk which nuclear energy poses to the inhabitants of the great cities provokes angry manifestations.

It is fundamental that if human beings want to have a reasonable availability of energy, they must try to do so minimizing the negative impact on nature and on all human beings no matter what their social condition may be.

5. Energy Planning and Policies

The complexity of the problems set out above; the great inertia of energy systems on the supply side and in relation to cultural and social

(4) It must also be taken into account that a great part of deforestation is due to indiscriminate felling of woods for timber purposes, for opening up new accesses and freeing land for agriculture and cattle-raising.

consumption patterns; the limitations of human, natural and capital resources which the developing countries face for solving their energy problems; the evident ineptitude of imperfect or non-existent markets for ensuring a just, reasonable balance between requirement and provision in the short term; the impossibility of even the most perfect market mechanisms to solve inter-temporal conflicts and to adequately consider environmental problems; mean that proper energy planning must be made within the framework of overall socio-economic planning.

In the Western world, some developing countries like India and Argentina were among the first to resort to these techniques back in the 40's. Subsequently Europe, during the 50's, faced with extreme situations similar to those which many developing countries are enduring today, also recognized and applied extensive energy planning. Today, after the crises of 1973 and 1979, almost all countries and international organizations recognize the need for this planning, although with different techniques and approaches.

If the developing countries are to be able to carry out this energy planning adequately on the basis of each country's resources and its own problems and interest, it is necessary to form technical teams without delay, duly trained for these tasks and with suitable access to the real power levels of the Government.

It is also essential that the planning system, not one plan in particular, be structured in such a way that it gives maximum social participation to all the actors involved: users, producers, workers, professionals, enterprises, local, regional and national groups.

Planning must be a continuous, iterative process which, beginning with the establishment of energy requirements compatible with an integral human development scenario in accordance with a life style chosen by the whole population, would seek its accomplishment with a provision system having the maximum degree of autonomy, safety and fairness and the minimum socio-economic cost compatible with the above objectives.

The provision and consumption system must aim at maximizing the positive effects on the socio-economic system and minimizing the negative ones. Implementation of the resulting plans will require the adequate preparation of concrete projects, design of suitable policies and the operation of an efficient management control.

In this area of specific policies, I consider it necessary to point out some which are highly important and which possibly do not coincide with some objectives widely publicized in recent years.

5.1. In the field of energy *prices or tariffs*, it is considered necessary to take very specially into account that in the developing countries assumptions about equitable income distribution upon which orthodox tariff systems are based, are not even approximately fulfilled. In the face of this reality, it is necessary to undertake a careful discrimination of markets and to give prices and tariffs of energy products below the theoretical values for the lower-income sectors and above them for the higher-income sectors. These mechanisms which have recently been put forward, even in World Bank publications, would permit satisfaction of basic energy needs of the former to be assured, and they would avoid the excessive use and environmental deterioration caused by the latter, without affecting the budgets of supplier companies and even generating higher total incomes for them than the present ones.

In the case of oil derivatives, price differentiation should be given by product or by region. For example, luxury consumptions (gasoline) should be surcharged through taxation and those connected with basic needs (kerosene) subsidized. In some countries with large supplies of natural gas, this could be a product which would facilitate the provision of fuels at differential tariffs, similar to those proposed for electricity.

Regional tariffs are important for slowing down the rural exodus and encouraging development of the peripheral areas.

5.2. In *rural and marginal urban areas* programs of technical and financial assistance should be designed which would enable users to have access to suitable equipment making efficient use of traditional fuels possible and their substitution by non-conventional energy sources or by commercial sources (oil derivatives, gas or electricity).

5.3. In all sectors suitable financial mechanisms should be put into effect to facilitate the development of *energy conservation* (for which there is a wide field in the developing countries in spite of their low total consumption) and for the introduction of non-conventional energy sources which may be more advisable than the conventional ones from the macroeconomic viewpoint.

5.4. Establishment of suitable *financial mechanisms* for channeling the local savings capacity normally existing in the medium and high income sectors of the society, to finance energy production, transport and distribution schemes.

5.5. Design intensive *training* programs at all levels, taking maximum advantage of local or regional possibilities and those of other areas in countries of the South which have a higher relative degree of development at least in some particular fields.

This effort should be complemented with more specialized formation in the developed countries.

In this sphere, it is also important to change the pattern of technical assistance and cooperation of the developed countries so that their programs would aim at consolidating institutional development of teaching and research in the developing countries themselves, thus avoiding the permanent "brain drain" from developing to developed countries, as some international institutions like the United Nations University and the European Communities Commission are doing in the last years.

5.6. *Industrial development* policies oriented towards increasing local and regional participation in the supply of material and equipment to a reasonable maximum for the development of the energy system. In this field, cooperation at regional level and between developing countries, backed up by technology transfer, adaptation of technology and technical assistance by the developed countries is of the utmost importance.

Summarizing, we can try to define an energy policy adapted to the developing countries as follows:

The Energy Policy of the country must aim at meeting the direct and indirect energy needs of each and every inhabitant, in the short, medium and long term. For this there will have to be a rational, balanced use of available energy resources, at the lowest possible social and environmental cost, within the context of the evolution of the whole national socio-economic system, contributing to the independence and security of the country's energy supply. [10]

6. International conditionings

So far we have referred fundamentally to the energy system as such and to its relations with the socio-economic system at national level, but we should not forget that both are inserted in an international system which limits and conditions them.

It is also necessary to remember once again that energy is not the only nor the main problem of society in LDC's but rather an appropriate instrument for helping to solve the more general socio-economic problems. In other words, it is a necessary condition but not a sufficient one.

During many decades the international system created highly unfavourable conditions for the human, social and economic development of the developing countries. Before concluding, therefore, we consider it necessary to refer briefly to some of them.

6.1. *Deterioration of terms of trade*

Through the years the terms of trade between developing and developed countries, over and above cyclical short-term variations, have undergone severe deterioration and have been converted into a source of transfer of real economic resources of the developing to the developed countries. A perfect example of this is given by the case of oil itself, whose real prices declined systematically between 1950 and 1973, contributing to a great extent to the reconstruction and expansion of Europe and Japan after World War II. The oscillations which have occurred in the last 10 years prodded by the OPEC and tolerated or even fomented by some developed countries interested in exploiting their own high-cost resources, have been nothing more than the partial recovery of the earlier transfer.

In recent years this deterioration has accelerated for non-oil producing countries, reaching the lowest levels in the last 50 years in many cases. [11]

How can the developing countries save, accumulate capital and pay their debts if their exportable produce is continually being devaluated vis-à-vis the cost of industrial products and the financial costs of capital, while at the same time access to the markets of the developed countries is being closed to them?

6.2. *High real interest rates*

To the traditional problems of negative trade balance, a new mechanism has been added in the 80's which squeezes resources out of the developing countries for financing a large part of the developed countries' budget deficits and their enormous military expenditures. I am referring to the real interest rates which traditionally varied between 2-3% per annum and which at present are reaching levels of 8 to 10%, i.e., 3 to 4 times higher, which makes payment of debts and their interest practically impossible, with the meagre income from exportations limited by the drop in prices and the barriers to international trade.

In this last respect there exist nowadays a heavy protectionism and a policy of export subsidies for primary products, that will hurt the development — and even will speed up the underdevelopment — of the LDC's. (This is the case of European subsidies for their agricultural exportations and the United States barriers to the imports from LDC's of some primary manufactured goods as steel).

6.3. *Lack of technology transfer and its adaptation*

At the present time, the developed countries are unwilling to make real transfers and adaptations of advanced technology to developing countries. On the contrary, on many occasions they try to transfer to the latter obsolete products and technologies or complete production lines which are highly contaminating or require working conditions which are no longer acceptable in the countries of origin, or conversely, they try to use the developing countries as laboratories for testing technologies not yet developed, as in the case of the non-conventional energy sources.

6.4. *Inadequate mechanisms of technical and financial assistance*

In many cases, with some honorable exceptions, the so-called technical or financial assistance programs are nothing else but mechanisms to: a) finance the exportation of industrial products from the developed countries themselves; b) provide occupation for their unemployed technicians and professionals; c) carry out pilot experiments of technologies not yet used in their own countries; d) undertake potential market studies for their own exportable products, instead of seeking the development of local human capacities, the use of their own natural resources and the design and development of technologies adapted culturally, socially and economically to the real situations of the developing countries.

These are only some of the conditionings which the international situation imposes on the developing countries, not only for solving their energy problems but fundamentally for beginning to achieve a fairer, more human life for millions and millions of people created by God in His own image, and without distinction of races, languages, religions or cultures.

These problems have been described frankly and earnestly, perhaps with a little over-emphasis, but I believe it is essential to do so, to call a spade a spade and to try to make a realistic approach to the problems which today confront humanity.

There is no doubt that many programs, institutions and persons exist which are not guided by the above motives and in that sense there has been some remarkable progress in recent years but they are still a small part of the total, and mass conversion would be necessary if we want to achieve concrete positive effects in the short and medium term. What is at stake is not only the lives of millions of human beings in the developing countries but fundamentally the survival of the whole human race, both in the developed and in the developing countries.

The leaders of both bear the heavy responsibility of knowing how to bring about change in an orderly, voluntary fashion before the incapacity and obstinacy of human beings lead us all once again to undergo those same changes in disorder and violence.

7. Summary and Conclusions

— Energy is not an end in itself nor does it constitute the main problem of the developing countries. It is, however, a necessary and very important instrument for achieving integral human development. "Of the whole human and of all humans".

— For studying the energy problem in the developing countries, it is necessary to adopt an analytical, detailed approach that, starting out from human needs, will determine which are the socially necessary requirements to ensure the equitable provision of survival and comfort needs and of the production requirements of society.

— From this determination, it is necessary to look for the most suitable combination of provision from the various energy sources, in particular those of local origin and of a renewable nature, complemented from abroad if necessary and advisable.

In this latter case, regional cooperation between neighboring countries constitutes a convenient, desirable instrument.

— In the design of this balanced energy system of requirements and provision, particular care should be taken to maximize the positive impacts on the socio-economic and cultural system and to minimize the negative impacts on the natural and social environment.

— To enable the local systems of the developing countries to put into effect an integral human development process at a reasonable rate, it is necessary that the conditions of the Old Colonialist Economic Order be changed substantially and a New, collaborative, Socio-Economic Order be established, based on the humanist principles shared by all the great religions of the world and clearly expressed in Holy Scriptures and in the Social Doctrine of the Church.

REFERENCES

[1] *A regional Energy System, The Entre Rios Province (Argentina)*, IDEE, December 1982, San Carlos de Bariloche, Argentina. Report prepared for the IDRC.

[2] *Methodology for the Study of Energy Requirements in the Developing Countries*, IDEE, February 1982, San Carlos de Bariloche, Argentina. Report prepared for the EEC.

[3] *Study on the Future Requirements of Non-Conventional Energy Sources in Latin America*, Fundación Bariloche, July 1979, OLADE-UNDP, Quito, Ecuador.

[4] McGranahan G. and Taylor N., *Patterns of Urban Household Energy Use in Developing Countries: The Case of Mexico City*, IER, Institute for Energy Research, Stony Brook, USA, 1977.

[5] *Energy Needs, Uses and Resources in Developing Countries*, BNL, 1978, prepared for US AID. Quoted and amplified in [3].

[6] *Fenomenologia e modellazione della domanda di sussistenza*, Energia Domani, No. 31/32, CESEN, Taken from Rural-Urban Household Energy Survey, Ministry of Mines and Energy, CESEN, Addis Ababa, 1982.

[7] *Methodology for the Study of Energy Provision in the Developing Countries*, IDEE, February 1983, San Carlos de Bariloche, Argentina. Report prepared for the EEC.

[8] Suárez C.E., *Human Resources and Training*, IDEE, Presented at the Seminar "Energy and Development", July 15-18, 1980, FLACSO, ILDIS, OLADE, Quito, Ecuador.

[9] Suárez C.E., *Energy Planning Methodologies and Personnel Requirements*, IDEE. Presented at the UN Symposium on Energy Planning in the Developing Countries, Sept. 28 - Oct. 2, 1981. Stockholm, Sweden.

[10] Suárez C.E., *Energy Policy*, November 1983. Lectures at the XIIIth Latin American Energy Economics and Planning Course, San Carlos de Bariloche, Argentina.

[11] *Preliminary Economic Balance of Latin America in 1982*, ECLA Notes, No. 373, January 1983.

[12] Pellegrini V. (S.J.), *Viedma Episcopate.* Rio Negro, Argentina, Personal Communication, May 1984.

ENERGY AND DEVELOPMENT

MAURICE FOLEY
European Community
VIII Development, Rue de la Loi, 200
1049 Brussels, Belgium

Without energy there cannot be development. The fact that energy is as old as human history itself clearly illustrates this. Wood, charcoal, crop residues, and dung provided the energy for cooking, without which most of our food would have been indigestible. The same sources provided warmth in cold climates. Even today, close to half of the world's population, and the vast majority of people living in the rural areas of the developing countries, depend for cooking and heating on these traditional fuels. Wood and charcoal traditionally provided the energy for making bricks and ceramic ware, and for welding and forming metals. The industrial revolution of the seventeenth and eighteenth centuries, which provided the impetus for modern economic development and growth, would have been impossible without a dramatic increase in the use of energy. Steam engines, fired initially by wood, but later mainly by coal, provided the necessary mechanical energy for mining, water pumping, manufacturing, and the propulsion of ships and locomotives. Coal, converted into coke, became the main source of energy for steel production. Towards the end of the 19th century, electricity produced from high pressure steam and the force of falling water came into widespread use — both as a source of mechanical power and artificial illumination. At the same time, the internal combustion engine made its appearance, revolutionising the industry. Electricity also became the exclusive energy for the growing telecommunication industry. Telephone and telegraphic systems, and more recently, the cinema, radio and television all depend on the use of electricity as their source of energy. Modern computers could not function without it. Another major user of electricity became the electrochemical and electrosmelting industry. Without electricity many products such as aluminium, magnesium and titanium, high-premium zinc and copper, to name but a few, could not be produced or could be produced only at a very high cost.

The invention and widespread use of the internal combustion engine and, later, gas turbines would have been impossible without the availability of highly refined petroleum products.

Clearly, without the easy use and ready availability of these various sources of energy we would not be in a position to produce the volume and variety of goods and services that enable so many people (particularly those in the industrialised world) to live more varied, more productive and healthier lives than their forefathers. All of this is well known to you but I repeat it here in order to show the degree to which we owe *our* development to the availability of energy resources. It is a lesson we must keep in mind when considering how we can assist developing countries in their efforts to produce in their societies a similar rapid progress to that which we have known in our own.

Until the "golden sixties" energy had never been considered as a problem. However the unprecedented growth and development in the western world, particularly since the end of the second world war, together with the developing economies of the Third World countries, had created a growing pressure on the energy markets. An abundant supply of cheap oil had pushed out older sources of energy (especially coal) and had discouraged initiatives aimed at diversifying sources of energy in the Western world but also in the emerging modern sectors of the developing countries. It was the *oil crisis* that really underlined the vital role of energy in economic growth and development and the extent to which it had been neglected. "Energy" soon reached a point where it virtually reached equal status with the three traditional factors of production: labour, capital and land.

Though the immediate effects of the oil crisis may have been felt most by the oil-guzzling modern economies of the Western world, paradoxically enough it is in the poorest countries and areas of the world that the energy crisis may have the most serious and the most long-term adverse effects on development. In most of the developing countries energy has become as worrying a constraint on development as food. Economic development in these countries is particularly dependent on energy since every percentage point of economic growth generally involves more than one percentage point increase in energy consumption. Thus it is that latest estimates claim that developing countries will use two-and-a-half times as much oil by the year 2000 as they do now. Their share in world commercial energy consumption will have increased from a fifth in 1980 to just over a quarter by 1995. This means that almost half of the expected increase in global energy consumption over the period 1980-1995 will take place in the developing countries.

As if the oil crisis were not a sufficient challenge and constraint to development in the Third World, a second energy crisis in the meantime has been growing very rapidly, this time in fuelwood. It has hit many developing countries harder and more painfully than the oil crisis as it is on basic needs rather than in factories and on the roads that its adverse effects have been felt most. Not surprisingly, the fuelwood crisis has commonly been referred to as the "poor man's energy crisis". More than 2 billion of the 4½ billion people on our globe rely on wood, charcoal and other various materials such as crop residues and dung for the cooking of their food. The overwhelming majority of these 2 billion people have no alternative source of cooking fuel. A lack, a shortage, an increase in the price of fuelwood automatically means a deterioration of their standard of living which is often already at, or beneath subsistence levels. For example, in Africa south of the Sahara, more than 180 million people are now suffering because of a lack or shortage of fuelwood. Contrary to what is often thought, the traditional use of wood-fuel as a "cooking fuel" in the rural areas of the developing countries is far from being the main cause of this woodfuel crisis. Wood clearance for agriculture and the demand for charcoal from the mushrooming urban and sub-urban populations of developing countries are the main culprits behind rapid deforestation and desertification. FAO estimates that more than 10 million hectares of forest disappear every year compared to the only 1 million hectares that are replanted. Drastic measures are needed in order to restore the situation.

Conscious of the crucial role which energy plays in development in general as well as of the serious constraints which both the oil and woodfuel crisis put on development efforts in the Third World, the European Communities cooperate with a number of developing countries in the field of energy. These cooperation schemes involve countries associated under the Lomé Convention, countries with which the Community has concluded specific agreements particularly in the Mediterranean and also countries where only one-off operations have hitherto been carried out. It is to these energy cooperation schemes between the Community and various developing countries that I would now like to turn.

I suggest we have a brief look at the past first.

Energy cooperation has been a component of Community development operations since the entry into force of the EEC Treaty. It is true that the level of activity was modest up till the first oil shock, which promoted energy matters to the forefront of awareness. Consequently, from 1975 to 1980 energy cooperation grew considerably. Even though energy was not laid down as a priority under the first Lomé Convention, aid under the Convention was three-and-a-half times as much as in the eighteen preceding years of cooperation, and five times greater from the standpoint of the real impact on the ACP countries through the multiplier effect of cofinancing.

This period was also characterised by the increased importance of new forms of energy, both under Lomé I and under new instruments such as the bilateral agreements with the Mediterranean countries, aid to non-associated developing countries, financial assistance to the activities of Non-Governmental Organisations (NGOs), and in national budget resources allocated to energy programming. Under Lomé II, while the importance of energy was acknowledged and despite the studies undertaken by the Commission, the energy provisions were limited in scope and did not contain very clearly established guidelines.

The second oil shock finally convinced both sides of the importance of an overall approach in energy cooperation. A detailed look at the contribution of energy cooperation to the energy development of the developing countries enables us to learn the lessons to guide our future operations.

At 31 December 1983 total funds allocated under Lomé I and II for energy development from the Community's institutions amounted to 525 MECU (approx. $ 500 million, taking into account the fluctuations in the exchange rate over the period), which was more than 10% of the Community's total financial commitment towards development. Nearly half of this amount (47%) came from the Commission either in the form of grants or special loans. The other half (53%) was channelled through the European Investment Bank in the form of subsidised loans and risk capital.

More than 90% of the funds were devoted to projects of the traditional type — large hydro-electric dams, power stations and transmission networks. These projects certainly raised the rate of energy self-sufficiency but they did not contribute sufficiently to development. In particular, it is found that such capacity is under-used, which raises the question of the appropriateness of the structures concerned to the real needs of countries whose vastness would seem to call for diffused rather than concentrated energy systems. Establishment of the structures has sometimes had harmful consequences for the environment and for rural society: for example the disappearance of flood-water cultivation on the banks of the Niger, the destruction of living creatures through flooding at Lake Chad.

The electrification of Rwanda serves to temper criticism of large-scale structures since it was carried out quite successfully, though admittedly under very favourable conditions such as a population density of 200 inhabitants/km^2. The Rwanda case could stand as an example because of the way it was carried out and integrated into the country. The construction of hydro-electric dams should be reconsidered in the light of development priorities; this is a prerequisite of determining their future role in energy cooperation.

Although new forms of energy have not played a large part (5%) in energy cooperation, the approach adopted merits attention. Aware of the difficulties of introducing new technologies, the Community has always taken a cautious line in developing new forms of energy in developing countries. Financial risks were reduced to a minimum and the technologies used were selected from among the most thoroughly tested. New forms of energy were used as components of larger projects (irrigation projects and so on) and the maximum amount of care was given to having them accepted by the population. Cooperation with NGOs accounted for a large part of the success of operations undertaken in the fields of solar energy, geothermal energy and the development of biomass production. These results, and those of cooperation activities undertaken with the Southern Mediterranean countries and non-associated developing countries, as well as the special "energy" budget lines of the Commission, are an encouragement to the Community to go further. Permit me to give a few examples here.

The Community is at present financing from its own budget a large-scale study of a biomass system aimed at the possibility of industrial-scale use of wood and other cellulose waste as a domestic fuel in place of fuel wood. This study forms part of the question of large-scale use of new forms of energy, which the Commission is at present looking into. In Zaire, the Community supports a scheme whereby 750 rural health centres are equipped with photovoltaic generators that provide electricity for lighting as well as for refrigeration of medicines and vaccines.

In Sri Lanka, following several years of development work the design of a tea manufacturing process was drawn up in which a major portion of the heat required for drying tea is derived from solar energy, thereby saving up to 25% of the fuel consumed in the present conventional tea factories. There is a great possibility that the same process could be adopted and used for tobacco drying.

In India, a study was carried out on energy saving in the artisanal fishing industry. Over the last 20 years considerable progress has been made in mechanising artisanal fishing boats in developing countries, by fitting diesel engines or outboard motors. This has improved fishing capacity as well as safety. Unfortunately the value of these improvements has now been overtaken by the increased prices of oil which sometimes represent half of the total cost of the fishing operation. The study has developed a simple methodology for quantifying fuel efficiency of existing boats and has identified the most important areas where design changes will lead to improved fuel efficiency.

Since 1978, energy programming operations have been carried out in different developing countries. Their purpose is to provide an in-depth analysis of the energy needs of developing countries and to help them identify their needs. Cooperation takes the form of assistance with the establishment of energy balance sheets, specific on-the-spot assessments, training schemes and, lastly, support for a cooperative research project involving institutions in all the continents. As a result of these operations, relations have been established with experts from all the countries concerned, who are now cooperating in working out new techniques for evaluating energy demand.

So much for the past. Let me now turn to the future.

Let me start with our objectives. The first objective concerns the choice of priorities and sectors — a choice necessitated by the restricted resources available. The great diversity of the developing countries also makes it necessary to take maximum account of each country's specific energy requirements. The Community and its partners determine together which schemes best reflect the concept of mutual cooperation in order to estahlish the conditions required for their joint development.

The second objective involves re-emphasising the importance of the economic, social and cultural context of each developing country in the interpretation of energy cooperation schemes. The schemes must be integrated into this context. Experience has clearly shown that if they are not, they will fail.

The third and probably most important objective is that the schemes must produce real development on as wide an economic basis as possible. Energy must *not* become an end in itself, it must remain a means to bring development, particularly where it is needed most.

In the developing countries, energy at present takes the following three forms:

(i) *mechanical* energy, including human labour, animal traction, water and wind power;

(ii) *heat* energy, including conversion of solar energy for drying as well as burning biomass and fossil fuels;

(iii) *Electricity.*

Working out lines of action in such a context means adopting priorities which are compatible with the objectives of development. These priorities are determined by a dual requirement:

— firstly, taking into account the diversity of the energy sector means acting at all levels of human activity, (i.e. survival, comfort, production) through the development of many forms of energy, (i.e. traditional, fossil and renewable.)

— secondly, the need for an overall, integrated view of the problem, which is essential for improved management of resources and calls for horizontal operations such as energy programming.

Let us now examine in more detail the priorities adopted by the Community in the field of energy cooperation and development in the Third World; firstly in the field of specific operations; secondly in the field of horizontal operations:

SPECIFIC OPERATIONS

Exploitation of fossil fuels

The development of fossil fuels — oil, gas, coal and uranium — some of which could be exported to the Community, is of direct mutual interest, particularly for the oil-importing countries, and deserves priority. It is also one of the fundamental prerequisites for industrial development in the developing countries. Mining cooperation, to which we attach great importance and which also seeks to develop fossil fuels, will prove very useful in this connection.

Relatively little is known, however, about the extent of fossil fuels in the developing countries. There is not enough exploration and the level of exploitation is often low in relation to known potential. The development and optimal utilisation of local oil resources immediately produces a saving in terms of foreign exchange. The Community therefore aims at cooperating in the spheres of exploration and preliminary investment as well as in the field of improved marketing; here, for example, the study which the Community will support in the SADCC regions aiming at an improved regional supply of oil products through improved refining, transport, storage and distribution systems and management.

The development of gas is closely linked with the structure of the country concerned. The use of gas in domestic and industrial sectors is subject to an overall strategy and for the moment exporting seems to be the main concern. It is, however, an energy form available in many developing countries and recent studies indicate that developing gas for domestic uses often provides much greater benefits to the economy, which can also be realised sooner, since such investments mature much more quickly than those for exports. In countries which are already engaged in gas production, like Bangladesh, Bolivia, Cameroon, Egypt, India, Morocco, Pakistan, Tanzania, Thailand and Tunisia, figures have confirmed that the cost of gas or the distribution rate is far below the cost of imported petroleum products. Cooperation should consequently also help to develop and use gas revenues for domestic purposes.

The situation is fairly similar for coal. The lack of transport infrastructure is an obstacle to export and hence to production on a sufficiently large scale. The possibility of mining small local deposits must be examined, even though production costs are high at present. I can tell you, for example, that in negotiations for the Lomé III Convention particular attention is being given to the development of the small, artisan mining sector in the ACP countries.

For large deposits, the only viable economic approach involves production geared mainly to export, with only a small proportion being used to supply national or regional fossil-fuelled power stations.

In countries with mining potential, such as Botswana and Niger, the Community contributes both to the development of resources and to the establishment of infrastructure, since the latter is a factor which in itself generates development.

Control of the use of fuelwood

The importance of fuelwood as a source of energy in the developing countries has been highlighted before. These countries depend on this universal fuel for over 50% of their total energy consumption. The ease with which wood can be used in traditional environments gives it a special place as a fuel which the developing countries cannot do without. If the production of wood could be organized and its use rationalised, it would remain an ideal fuel for meeting these countries' requirements for a few decades to come.

The production stage often involves only the random felling of trees and brushwood. These felling operations must first of all be rationalised by improving the management of the natural forest cover, through appropriate legislation and also replacement by reafforestation.

The distribution of wood can be improved, notably near urban centres. Since the price of wood largely reflects the cost of transporting it, transport must be rationalised by making the distribution channels as efficient as possible and reducing the volume of wood to be transported.

The processing of wood into charcoal causes a great deal of wastage as the techniques are rudimentary. The use of more efficient methods produces a major improvement and is fully justified where there is concentrated demand (urban centre or industry), provided jobs are protected.

The energy yield of wood used in domestic fires and in small industries is very low. Traditional household methods of building fires, such as the African fire using three stones, produce a yield of around 5%. This can be doubled by the use of more efficient stoves. The first programmes for the large-scale distribution of such stoves have revealed the difficulties which the population has in adjusting to them and underline the complexity of the problem, one feature of which is the difference of approach between urban centres and rural areas. The introduction of more efficient stoves is therefore a delicate matter, requiring the utmost caution and above all the integration of their use into the social, economic and cultural context. The industrial sector is, however, better prepared and provides a focus for action which is bound to have a trigger effect.

The present crisis cannot be overcome merely by improving the use made of wood. A substitute fuel must be found. The solution with the most potential seems to be the use of lignocellulosic waste (forest and agri-food waste) not utilised for food or in soil regeneration. This could make agro-industry self-sufficient in energy and could also provide a valuable substitute for wood users. The use of fossil fuels may in specific cases constitute another form of substitution, and this is an area where we hope to cooperate more with developing countries.

In general, success of cooperation activities in this field hinges mainly on an ability to motivate the population and it is important to examine beforehand the best approach and ways of providing this motivation, such as decentralisation, giving responsibility to those directly concerned, specific training, etc. The introduction of campaigns with specific themes is essential in the face of a complex problem of such size and scope.

The great importance which the Community attaches to the fuel-wood problem in the developing countries is reflected in the fact that special budget provisions have been made in the Commission's own resources to combat the fuelwood problem. In the 1983 budget, for example, an amount of 2.7 MECU was committed for programmes in Niger, Rwanda, Burundi, Haiti, Thailand, Nepal and South East Africa.

Development of water power

The Third World has considerable water power resources, amounting to some 65% of the world's resources. The potential is however unevenly exploited. In Africa, only 3% of resources are exploited, whereas in Asia the percentage is three times as large. Installed capacity for the developing countries as a whole is only one third of that for North America.

The development of water power, which has monopolized international aid in recent years, has led to an increase in the electricity generating and irrigation capacities of the countries and regions concerned, which have seen a great improvement in their energy self-sufficiency.

Water power seems particularly suited to meeting the demand for electricity from urban centres and industries which are major energy users. In the latter case, the building of the power stations must be closely coordinated in order to fit supply neatly to demand and avoid surplus capacity.

It is necessary to counter the harmful effects which the power stations sometimes have on the environment or on rural life. It is also necessary to make sure that the creation of concentrated sources of energy does not encourage even further the depopulation of the rural areas and uncontrolled growth of the towns.

The size of the countries involved and the dispersed nature of the requirements are further barriers to the expansion of water power.

In the past, a major proportion of the Community's contribution was given over to this sector. In the future, account will be taken of the changes on the oil market and in the structure of demand, which point up the need for operations leading directly to the exploitation of local potential, notably as regards the rational use of energy. It is obvious, however, that the development of the Third World's water power potential should not be abandoned.

In order to meet low-level demand from rural areas or from small and medium-size industries, the micro (1 KW - 100 KW) and the mini (100 KW - 1 MW) hydroelectric power stations have great potential. The technology is tried and tested and reliable, and the cost is reasonable although obviously higher per unit generated than with larger power stations. This promising avenue is still largely unexplored, however, because little is known about resources and attendant requirements, and also because of the lack of infrastructure in the areas concerned. The top priority is to make known the value of such a method of energy production, notably through microprojects.

Development of new and renewable energy sources

There are three factors which justify the development of new and renewable energy sources in the developing countries: first, the fact that they are decentralized, which makes them perfectly suited to the low-density consumption of the rural areas in particular; secondly, their great diversity, which makes it possible to use them in the various energy sectors of a country; and, lastly, climatic conditions which are particularly conducive to their introduction into the developing countries (sunlight, wind pattern, etc.).

The technology introduced must be tried and tested in order to reduce not only the financial risks but also the maintenance difficulties involved in the use of over-sophisticated technology. The equipment will in most cases be made available as part of non-energy projects (village water engineering, telecommunications, etc.).

Efforts must constantly be made to integrate these new forms of energy into the local context.

The priorities are as follows:

(i) development of the biomass, notably in conjunction with the problem of fuelwood. Some systems are already operational such as ethanol fuel, while others have yet to be worked out;

(ii) establishment of micro-hydroelectric power stations with mechanical and electric conversion;

(iii) the use of solar energy through static conversion by means of heat (heating of air and water) and electricity (photovoltaic conversion in the spheres of telecommunications, health, small-scale water engineering).

(iv) the use of geothermal energy, notably high-enthalpy energy for the generation of electricity but also low-enthalpy energy for the production of hot water and steam for industrial use.

The possibilities offered by wind energy, particularly in rural areas for pumping water, must be examined on a case-by-case basis. Continual updating, given the technological improvements in this sphere, is necessary.

Such is the state of the art at present that other new and renewable sources of energy remain in the background because they have not been sufficiently developed, are not economically viable, or are dispersed, which restricts their use. This is true of energy from the sea, although there is hope for progress here. The development of new and renewable energy sources must be pursued primarily through reliable and efficient operations which demonstrate the potential and usefulness of these sources of energy for development. It is likely that by the year 2000 increasing use will be made of them, although the forecasts made at the United Nations Conference in Nairobi in 1981 will probably not be realized in view of the cost and technological and technical problems.

The development of new and renewable energy sources in the developing countries must not, however, cause the continuing importance of human and animal power in these countries to be overlooked. In rural areas many requirements are met by this form of energy. Animal traction is still a major source of energy for agriculture. It is used on half the cultivated land in China and on an even larger scale in India.

For the countries concerned, which cannot convert from this form of energy without provoking dangerous imbalance in their economies and even on world markets, research and development schemes, operations to promote the use of appropriate equipment and planning can significantly improve their efficiency.

Operations that focus first on the assessment of potential, then on improving materials, vehicles and implements, and lastly on making this equipment more widely available are needed.

So far for the *specific operations*; let me now come to the *horizontal operations.* The aim of what are termed horizontal operations is to make people in all sectors of the economy aware of what is at stake in the energy issue, and so enable energy to be used sparingly and efficiently.

In order to ensure that developing countries can make it smoothly through their energy transition, away from oil which eats their scarce foreign exchange, away from fuelwood which destroys forests and creates deserts, each user must play an active part.

There are in the main three groups of horizontal operation, centring on energy programming, the rational use of energy, and a general set of operations covering research, training, information and evaluation.

(a) *Energy programming*

An essential tool in the formulation of energy policy, energy programming nevertheless takes different forms depending on the level of development and the energy situation of the developing countries.

In countries which have only very fragmentary energy data statistically haphazard or even lacking any system the first step is to develop information on energy. The prime objective of cooperation in this sector is to create the means of drawing up annual balance sheets and forecasts and of interpreting them.

In the newly industrializing countries this work is more complex and involves economic analysis and the interaction between the various economic and energy sectors. The greater volume of figures and the better statistical framework make it possible to set up data banks and to use computers to process and make use of the information. Cooperation in these countries therefore comprises major programmes for the training of supervisory staff and technicians, and also joint studies and analyses.

Energy programming provides government authorities with a powerful instrument for preparing and making decisions. It goes beyond national to regional and local levels, and this means that it lends itself particularly well to regional cooperation.

(h) *Rational use of energy*

The rational use of energy makes it possible to ohtain a better yield from energy and encourage the use of other forms of energy to replace oil. It is a question of preventing oil consumption from rising exactly in step with any increase in national wealth.

There is great potential for energy saving in the developing countries, estimated by the World Bank at 15% of consumption for 1990.

Fiscal and pricing policies are factors which can have a very important influence on the rational use of energy. They must nevertheless be used cautiously; though they may enable energy consumption to be reduced considerably, they may also give rise to social or political difficulties or even — if they result in excessively high prices — discourage or slow up industrialization. All sectors of energy activity are concerned. In the domestic sector, which largely involves fuelwood, the promotion of substitute energy forms is one of the best ways of improving energy use gain. It is nevertheless industry which offers the greatest potential, mainly through the improvement of the technology for production and use. The same applies to transport, where there is slightly less room for saving but which accounts for a very high proportion of the consumption of energy, and particularly oil.

The Community's position here is to encourage the taking into account of the energy component as soon as a project is formulated, in order:

(i) to meet the project's energy requirements in the best possible way and align the means of production on what is strictly necessary in the light of real needs;

(ii) to use, as far as possible, equipment with low energy consumption and a high yield;

(iii) to study the variants which could be incorporated in a given project in order to make use of the various forms of energy and wherever possible allow the introduction of renewable energy sources.

Cooperation in this field also aims at improving the efficiency of the methods used, notably through the local production of energy-saving equipment, such as more efficient stoves. This is essential, since the greatest incentive to the efficient use of energy is a better quality/price ratio. The need to save energy is perceived only when there is an obvious financial saving.

The scope for energy-saving measures is immense, notably in the least developed countries, where there is often a very high degree of dependence on a single energy form. This applies to oil-exporting developing countries as well, since these countries often use their oil at below its opportunity cost.

The Communities' energy cooperation schemes would obviously be incomplete without a number of general operations to support and promote them. To conclude my speech, I would like to say a few words about these general operations.

Training, necessary at all levels, is particularly important, since it should provide the developing countries with human resources capable of coping with the complex nature of energy.

The Community's action takes the form of two complementary contributions: one geared to training specialists in the most modern techniques, and the other to training the maximum number of people in elementary energy techniques for use in rural areas.

Research and development, extended into demonstration projects, provides essential support for cooperation, notably for the development of renewable energy sources. Efforts are concentrated on applying the findings of European research in the developing countries.

This presupposes a wider dissemination of information, since it is not unknown for a numher of research institutes to undertake similar studies within a few months of one another. Evaluation of research is essential in order to determine which topics are of importance and to prevent studies from being excessively fragmented.

This, briefly, is how the European Community looks upon energy and its role in the development process. This is the way in which it is developing energy cooperation with developing countries.

DISCUSSION

CHOUCRI

Demand, as Professor Suárez has told us, is essentially an economic term that reflects a willingness to purchase in an established market and in an established form of exchange. It says nothing about the ability to purchase, or about need. Need as a concept has no place in conventional economic assessments and calculations.

My second observation concerns the concept of technology transfer. I must remind you that this is a diplomatic term. In reality technology is bought and sold in commercial markets.

Finally, the energy issue is just one element in an extremely crowded agenda for all governments, in developed and developing countries. We also have to bring the private sector into the scene. How, and with what incentives is something we should discuss in the days to come.

SUÁREZ

I agree completely with Miss Choucri. The concepts of demand and need are quite different. What I wanted to stress is that we have to develop unconventional economics because we are faced with unconventional problems and situations. I also agree that technology is a commodity. In my opinion it is the most valuable one you can find in the world market.

I think you are right, we have to try to find out how the private sector can help governments to find good solutions.

DI VECCHIA

Prof. Colombo stressed that energy-related problems in LDCs are one of the aspects of poverty, together with malnutrition, starvation and health disease. My point is that making energy more available in an LDC does not guarantee that development will take place. We have to know where this energy goes, we need a better understanding of the local economic structure. Financial help, also, has to be targeted in order to optimize investment. The case of Sahel is an important testing area for energy problems, but again energy is one of the many problems that this area is facing.

Boettcher

Two questions to Mr. Foley. Cooling of agricultural crops is one of the important ways to decrease post-harvest losses. Does the European Community promote cooling by the solar absorption cycle for this purpose?

It is known that wind energy has substantial potential depending on the local available average wind speed. Does the Community have programmes to measure wind speeds on a significant number of potentially interesting sites?

Foley

I do not know the answer to the first question, but I will write you on that. We are starting our activities in the wind energy field, and on this subject as well I will send you all the available information.

Menon

Given the international trade environment, it seems to me that developed countries ought to see that it is in their own interest that energy development programmes in the LDCs receive financial support. That is the only way in which LDCs can have a greater purchasing power, that there can be larger markets, greater interdependence.

I want to go back to the concept of technology transfer regarded purely as a commercial buying-selling transaction. That is certainly true in the bulk of the cases, but sometimes we tend to look at these things in terms of what will be a very limited scenario of a very small profit centre. If we enlarge the scenario taking into account the overall interests of both the developed and developing countries and some larger profit centres, the complexity of technology transfer will clearly emerge. It is not purely commercial activity.

Goldemberg

I want to support the point of view of Miss Choucri on the need of supporting the role of national governments in trying to define and improve the self-reliance of LDCs. The tendency to regard the well-meaning effort of developed countries and international organizations as pre-marketing efforts has a lot to do with the fact that too many of these projects lead nowhere.

MALU

Mr Foley, has the Community any project to promote the rational use of energy, in other words, what is the EC doing in order to help people to manage their energy demand?

LANDSBERG

Dr. Suárez, I have some comments on your presentation. You said that small increments of energy availability produce large improvements in the quality of life. You also pointed out that there is a connection between family size and energy consumption. In this case your conclusion was that the larger the family the better, because it uses less energy. It seems to me that there is a tendency to confuse correlation with causality. Given the large number of factors which take part in shaping the energy scenario, picking up two of them, plotting them one against the other and drawing a conclusion, may show a correlation but not causality. Another point you made was that a main energy problem in LDCs has been their low energy consumption level. We have a similar situation, of course, domestically, in the USA. The poor use less energy per capita. Well, the problem is not that they use less energy, but that they have less income, they cannot afford to buy more energy, and it is exactly the same on the international scene. The best and most efficient remedy, both domestically and internationally, would be to supplement income and let people buy more energy or buy something else if they want it. I do not think that lowering the price of energy would be a good solution. The problem, and again there is an interesting parallel both domestically and internationally, is that it is far easier to obtain funds for a specific energy project than modify income distribution or make general grants of money. So it is much easier to promote a policy to fund energy than to fund income. If in practice we cannot follow up and do something against poverty, that is a deficiency and we have to try to do our best to push for more in a category of income support and let those who receive it decide how they want to spend it. This is something which would please Miss Choucri, because the needs could be converted into demand. I think we are presumptuous if we think we know what others' needs are.

Dr. Suárez, I apologize if I have misinterpreted you, and I'll be happy to modify my judgment.

KHAN

I want to bring up again the theme of technology transfer. I think this issue is a key one between the industrialized and third world countries, in particular in the area of energy technologies. It is my impression that energy technologies have not been shared with the countries which show an energy deficit. Of course this is part of the overall picture of the reluctance to share technologies, because of their high value. There are financial aspects as well as commercial ones, but the key one is related to human resources development. Training of manpower in the technological field is what developing countries need. But we see that over the last few years there is a resistance to the acceptance of trainees in the advanced countries. What I think would be possible is some kind of joint effort in which the scientific know-how of the industrialized countries could be wed with the manpower and local resources of the developing countries, in order to develop, together, energy technologies which would have ready applicability. Industrialized countries have good technologies for developing countries, for example, those related to solar energy.

A joint effort means togetherness, and it implies the sharing of technologies, because their development must be accomplished in concert.

SUÁREZ

I agree with Prof. Landsberg that reducing the cost of energy is not the best solution, but we need a short-term solution, and tariff differentiation provides this. In the long term you have to increase the people's income. If you let a developing country follow only the market forces you will increase the differential between urban and rural areas. One has to make a trade-off between long-term and short-term solutions.

CHAGAS

Let me say that I agree completely with the point made by Dr. Khan. I think that the transfer of technology to LDCs can bring positive results if they possess a nucleus of scientific and technological knowledge. Otherwise LDCs will be completely under what I call technological colonization.

There is a second remark I want to make. Many times this Academy has stated that governments bave the responsibility of the development of the country they represent. This also goes for the development of energy. LDCs cannot hand over the responsibility of their own development to foreign countries. This has nothing to do with nationalism, it is only being rational.

THE PRODUCTION OF FOSSIL FUELS IN THE DEVELOPING COUNTRIES: A PRIORITY AND A HOPE

PIERRE DESPRAIRIES
Institut Français du Pétrole
92506 Rueil Malmaison Cedex, France

1. *Fossil Fuels, and Especially Oil and Gas, Are the Key to Development*

According to the forecasts made at the World Energy Conference in September 1983, world consumption of primary energy of all sorts should increase by nearly 5 billion tOE (4930 MtOE) between 1978 and 2000, going from 6820 to 11,750 MtOE, for an increase of 72 percent. The Third World countries alone will be responsible for nearly half (46 percent) of the increase in the world demand, i.e. 2275 MtOE. From one quarter (25 percent) of world consumption, the Third World share should rise to one third (34 percent), while the industrialized countries will symmetrically backslide (from 75 to 66 percent). This is the result of the world economic mutation which is slowing down the growth of energy consumption in the old industrialized countries and increasing it in the Third World, which is gradually becoming industrialized and improving its standard of living at a moderate rate.

This new demand for energy by the developing countries will zero in massively on fossil energy sources. Between 1978 and 2000, oil, natural-gas and coal consumption will increase by 1750 Mt, which is 76 percent of the total increase of primary energy consumption in the Third World. So-called renewable energy sources (hydroelectricity, wood, biomass) and nuclear electricity will provide for only 24 percent of the new needs.

The regression of non-commercial energy sources is spectacular, dropping from 37 to 19 percent of total consumption. Among fossil energy sources, oil and gas alone will cover 57 percent of these new needs, and coal only 19 percent. China by itself, an old coal consuming and producing country, will account for half of the new consumption.

Therefore, the period from 1978 to 2000 will see the confirmation of the position of fossil energy sources, and especially oil and gas, in the Third World. This evolution reflects some simple economic realities:

A. Primary electricity and new energy sources are advancing only slowly because they require heavy investments such as hydroelectric dams, nuclear power plants, distribution infrastructures, and, in the case of electricity, concentrated consumption areas (cities, industrial zones).

B. Non-commercial energy sources are backsliding because their production cannot keep pace with the growth in consumption linked to the population increase. In many countries, it is already impossible to speak of wood as a renewable energy source because the forestry capital is undergoing rapid destruction.

C. The better part of coal consumption is devoted to electricity production, which is being held back for the reasons that have just been mentioned.

D. The use of oil requires only a minimum of infrastructure and investments.

E. The supply of and market for natural gas exist on the spot in many countries.

These overall figures give some idea of the amplitude of the problem of mobilizing fossil energy sources for the Third World as a whole. The problem we are concerned with here is nonetheless more specific. It is that of countries whose growth is hindered, or may be hindered, by the need to import expensive oil: the oil-importing developing countries (OIDCs). Such imports for all developing countries in 1984 (according to a report by the IMF in May 1984) should represent 29 percent of their total imports, rise to 34 percent in 1987 and, with much luck and hard work, level off at around 30 percent in 1990.

The remarks that will be made will also concern the exporting countries, whether members of OPEC or not, which have small reserves, such as Ecuador, Indonesia, Egypt, Syria, Peru or Tunisia, all of whom run the risk of becoming importers in the next ten to twenty years.

To restrict us solely to the present oil-importing developing countries (OIDCs), the World Bank estimated in December 1983 that, between 1980 and 1995, their annual consumption of fossil energy should increase by 521 million tons, or 90 percent, in the space of fifteen years, or at a rate of nearly 4.5 percent per year.

Among the fossil energy sources of importance in the twenty years to come, it is oil and natural gas which must chiefly draw our attention.

The *coal* potential of developing countries is considerable. A survey by the IEA in 1982 estimated that coal production among these countries as a whole could double or triple, going from 177 MtOE in 1980 (265 Mt of coal) to 420 or 565 MtOE in 2000 (580 to 850 Mt of coal). Most of the production should be concentrated in six or seven countries: India and southern Africa (for more than half) and Korea, Colombia, Brazil, Indonesia and Mexico.

Coal is not the best energy source for development, except for countries that are already industrialized. For the others, the market would take a long time to create. Coal is 80 or 90 percent used in electric power plants and industry. The development of electricity is costly in investments and slow. A European country such as France took forty years to become completely electrified. Coal is of little use for countries which have not already begun to become urbanized and industrialized. It could be used, in principle, for household applications, but this raises practical difficulties. Coal is difficult to ignite, and lighting it requires wood or charcoal, which must be spared. Therefore, most future productions are destined to be a source of hard currency for *exports* mainly to old and newly industrialized countries. But the world market for steam coal hardly seems likely to take off before 1990 and perhaps even 1995.

Nevertheless, coal should remain a long-range objective for production and use in the developing countries. Its price is extremely low — $ 10 for the energy equivalent of one barrel of oil, which is around one third the price of oil. Its mobilization does not involve any exploration risks, and investments in a coal mine are much less than those in a giant oil field having the same energy capacity. Coal thus has a great future ahead of it. It has a potentially large market when oil prices again begin to climb. International coal trade should quadruple between 1984 and 2000, going from 200 to 800 Mt per year.

On the contrary, a large and increasing outlet exists for *oil* (Figure 1), the typical energy source of developing countries, because it can be transported in jerrycans, does not require much of an infrastructure, can be used for survival and the start of decentralized development in rural areas, and is usable for household applications (heating, lighting, cooking) as well as for transportation and industry. Once the present brief years of production surplus are over, oil will be able to be exported without any difficulty and at a good price throughout the entire world. The drawbacks of oil are that its production requires a great deal of capital — the unit of accounting for the development of a field is closer to $ 500 million than to $ 100 million — and more and more sophisticated technology because most giant fields which are easy to discover and exploit, have already been discovered. The average production cost of a barrel of "new oil" is now $ 15 to $ 20, whereas it was merely $ 5 to $ 10 less than ten years ago (Fig. 2).

Natural gas is destined to play an important role in the development of the Third World countries. Its worldwide reserves are still not very well known but are probably greater than those of oil. It is found in the same regions, using the same prospection methods. Its production and recovery are much easier and cheaper than for oil. On the other hand, it is a less convenient energy source because it is not greatly concentrated, and the cost of liquefying it and of pipelining it over long distances is much higher. These drawbacks make the exporting of gas over long distances not very profitable for producing countries, and except in a few special cases (Japanese market) few major projects for long-distance gas sales should come into being in the years to come. It is much more advantageous to use gas in the producing countries or in their neighbors. The World Bank

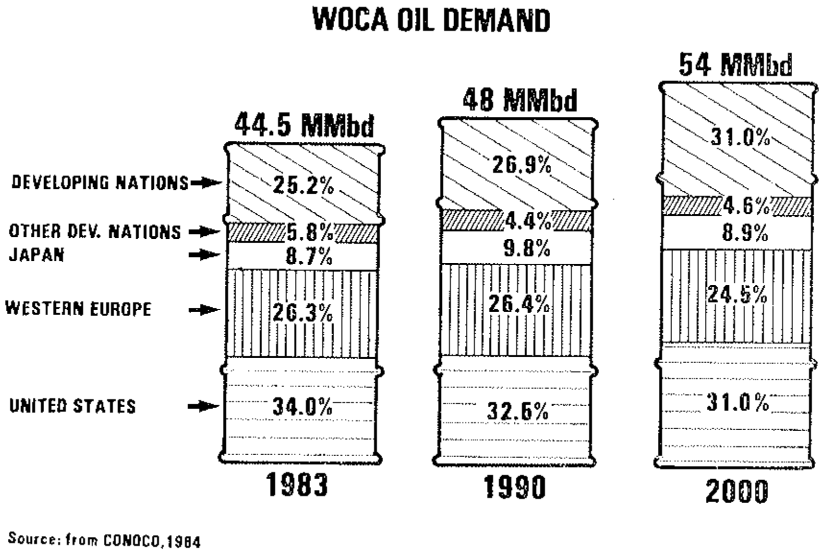


FIG. 1

OIL PRODUCTION COSTS AND INVESTMENTS

	Production costs $/bl	Investments $/bl/d
CONVENTIONAL OIL		
o MEAN VALUE	4	4000–8000
– Middle East	1	500–3000
– Non OPEC countries	8	3000–12000
HIGHT COST OIL		
o ROUGH OFFSHORE CONDITIONS	10–20+	10000–25000+
o DEEP OFFSHORE	15–30+	15000–30000+
o ENHANCED OIL RECOVERY		
– Water flooding	2–10	1000–5000
– Thermal recovery methods	12–30	8000–25000
– Miscible gas/CO_2 flooding	15–30	10000–25000
– Chemical flooding • POLYMER	15–30	12000–25000
• SURFACTANT	20–40+	15000–30000+
o HEAVY CRUDE[1]	30–40	40000–60000

(1): upgrading included

Source: IFP – Department of Economics–1984

Fig. 2

estimates that 70 percent of the gas produced in the Third World in the next twenty years will be consumed in the producing regions themselves.

Gas has multiple uses. If oil production already exists, gas can be used to recompress oil fields so as to obtain more liquid energy for domestic consumption or export. It is likewise advantageous to consume gas directly on the spot and to export one's oil. The use of gas for industry or for electricity production is very easy. In urbanized countries, gas can be distributed for household use. It is an ideal raw material for the chemical industry, and especially for manufacturing fertilizers. It can be used for manufacturing steel or cement. It can also be used as a fuel for cars and trucks, compressed in bottles or transformed into methanol or gasoline.

The development of natural gas will be greater and faster than that of coal, but it will be slower than that of oil because it will depend on the advances of industrialization and urbanization.

These are the reasons why the following remarks will be limited to oil and gas. Their production where they may exist in the subsoil is the first priority for the twenty years to come, in order to reduce the level of oil imports, the prime goal of any energy policy in the Third World.

2. *Why Is Oil and Gas Prospection So Slow in the Oil-Importing Developing Countries (OIDCs)?*

Over the last hundred years of prospecting for oil, 75 percent of the sedimentary areas of the Earth has been explored, including 450 out of the 600 basins. Therefore, it might be supposed that, if oil-importing developing countries do not produce oil, they do not contain any significant amounts to be discovered.

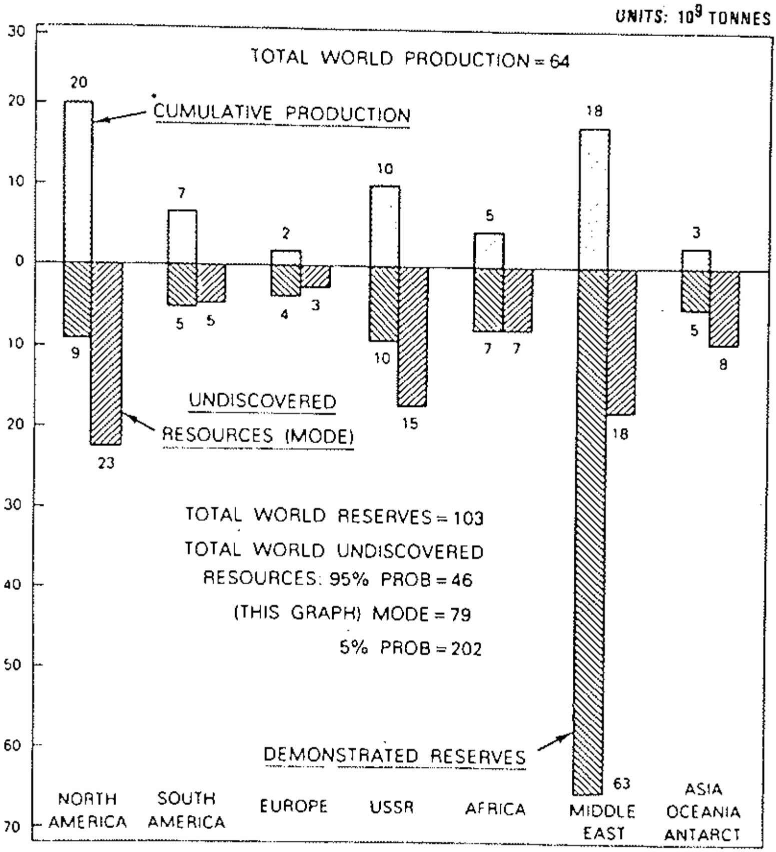
2.1. This is not the opinion of most experts. Most of the giant fields have probably already been discovered. But in the global crust probably still more than one half of the originally existing amounts still remain to be produced. A very large share of these potential resources is located in Third World countries outside of the Middle East. According to recent assessments by the most competent world experts, between 20 and 35 percent of ultimate world resources are involved (Figure 3). The World Bank estimates that oil production in the oil-importing developing countries alone could be more than doubled between 1980 and 1995, rising from 65 to 145 million tons per year.

But if there is lots of oil still to be discovered in the Third World, there is even more natural gas. The World Bank has said that the production of gas in oil-importing countries could be more than quadrupled during the same period, rising from 27 to 115 MtOE. Likewise, the IEA considers that, in all the developing countries not belonging to OPEC, the production of natural gas could be tripled or quadrupled, rising from 67 to 150 or even 250 MtOE per year between 1980 and 2000.

2.2. These potential resources are situated in what countries? Mother Nature has distributed them most unequally. The reserves in basins and the size of exploitable reservoirs may vary in a ratio from one to ten. In Latin America, for example, Mexico and Venezuela by themselves probably possess two-thirds of the reserves.

To make a finer analysis of the situation of the OIDCs, a distinction would also have to be made among the large countries with a high potential of energy resources, many of which are often newly industrialized countries (NIC), such as Brazil or India, and which can hope not to have to import any oil in ten years' time. On the other end of the scale there are some

REGIONAL DISTRIBUTION OF DEMONSTRATED RESERVES
AND CUMULATIVE PRODUCTION (1/1/1981)
AND UNDISCOVERED RESOURCES (March 1983)



Source: C.D. Masters, D.H. Root, W.D. Dietzman – Word Petroleum Congress, 1983.

FIG. 3

twenty countries which import more than 50 percent of their energy in the form of oil and which have only limited potential energy resources and a very low national revenue, such as Niger, Cambodia, Liberia or Haiti. These countries have little chance of making the grade without special and lasting assistance from the international community.

The countries already having proven reserves of oil and gas, even small amounts, are favored. The guidelines to discovery have been found, and they have much better chances of attracting investors. Furthermore, oil and gas reserves are generally concomitant.

BEICIP, a subsidiary of the Institut Français du Pétrole, made two surveys, one in 1975 and the other in 1982, in an attempt to make a case-by-case assessment of the situation of the oil-importing developing countries. The latter of these two surveys covers 93 countries. It reaches the conclusion that 30 of them have a good chance of possessing more than 100 million tons of recoverable reserves, and 30 others could have between 15 and 100 million tons.

2.3. Even if they are probably costly and small on the average, these future fields in oil-importing countries constitute financially profitable objectives for an oil company, provided that oil prices do not collapse. The promising discoveries in the last ten years in India, Brazil, Malaysia, Angola, Sudan, Cameroon and Colombia are good examples of this. They are much larger than the great majority of those found in the United States in the last twenty years, except for rare and brilliant exceptions (Alaska, California) at much higher cost.

2.4. However, these countries are severely neglected by worldwide exploration efforts. A survey made in 1981 by J. Favre and H. Leleuch of IFP (Figures 4 and 5) gives several significant figures. Between 1970 and 1982, 88 percent of the 141,800 wildcat wells drilled in the world (outside of the socialist countries) were concentrated in North America, 3 percent in the other industrialized countries, 4 percent in OPEC countries, 2 percent in oil-exporting developing countries, and only 3 percent in the oil-importing developing countries we are concerned with here. Likewise, oil-importing countries benefited from only 9 percent of the seismic prospecting done prior to drilling. However, an encouraging sign of change is the doubling of the number of wildcat wells drilled in the OIDCs, which have gone from 400 to 800 per year since 1981, even if this increase comes from only two countries, Brazil and Argentina.

Worldwide expenditures for petroleum prospection are extraordinarily concentrated in the United States. The 39 leading U.S. companies, out of a total budget of $ 51 million for exploration expenditures in 1982, spent only $ 6.7 million (13 percent) outside of the United States. Public and private European companies have also gone to work in the United States whenever they have been able to do so. In 1982, 50 percent of the kilometers of seismic profiles recorded in the world (1.4 million km out of 2.8 million km) and 76 percent of the wildcat wells drilled (18,250

EVOLUTION DU NOMBRE DE FORAGES D'EXPLORATION DANS LE MONDE

	1970	1975	1980	1981	1982	TOTAL 1970-1982	%
Amérique du Nord	9 250	10 860	15 773	18 305	18 848	162 641	88
Autres pays indus.	349	408	391	667	780	5 553	3
Pays de l'OPEP	386	469	420	491	463	6 183	4
Autres PVD	644	591	773	1 137	1 168	9 256	5
– dont exportateurs	(286)	(245)	(313)	(344)	(317)	(3 623)	(2)
– dont importateurs	(358)	(346)	(460)	(793)	(851)	(5 633)	(3)
TOTAL	10 629	12 328	17 357	20 600	21 259	183 633	100

Source: IFP/Département Economie – 1984.

FIG. 4

MESURE ET REPARTITION DE L'EFFORT D'EXPLORATION DANS LE MONDE (1970-1982)

	MOIS. EQUIPE DE SISMIQUE	%	FORAGE D'EXPLORATION	%
Amérique du Nord	65 810	61,5	162 641	88
Autres pays indus.	10 900	10	5 553	3
Pays de l'OPEP	12 300	11,5	6 183	4
Autres PVD	18 400	17	9 256	5
– dont exportateurs	(8 400)	(8)	(3 623)	(2)
– dont importateurs	(10 000)	(9)	(5 633)	(3)
TOTAL	107 410	100	183 633	100

Source: IFP/Département Economie – 1984.

FIG. 5

out of 23,900) took place in that country. The Mukluk well above the Arctic Circle in Alaska was abandoned as a dry hole in February 1984 after having cost $ 160 million. This sum is the result of drilling expenditures, but it does not include the amount spent for acquiring the permit prior to actual drilling operations, amounting to nearly $ 2 billion, all of which risks being a pure loss.

Yet it is obvious that U.S. petroleum resources are on the road to depletion and that such gigantic outlays are merely resulting in smaller and smaller discoveries. The following table shows the depletion of the U.S. oil and gas reserves (Figure 6).

Therefore, for the same expenditure in the United States in 1979, twice as little oil was found as had been the case ten years earlier, and five times less than twenty years earlier in the 1950s. The situation has declined since 1980 and has every chance of continuing to go downhill.

One consequence of this decline in U.S. petroleum reserves is the rise of discovery and development costs, as shown by various recent surveys. One of the most complete such surveys, made by the Arthur Andersen Company on the basis of the accounts of 300 private oil companies in the world, shows that the mean discovery and development cost of one

US HISTORICAL OIL AND GAS FINDING RATES

TIME PERIOD	CUMULATIVE EXPLORATION DRILLING (Billion feet)	FINDING RATE PER FOOT OF DRILLING	
		OIL (bbl)	GAS (Mcf)
1859-1949	0.0 – 0.5	236	916
1949-1958	0.5 – 1.0	51	347
1958-1967	1.0 – 1.5	21	252
1967-1977	1.5 – 2.0	20	186
1977-1979	2.0 – 2.1	9	134

Source: Conant and associates Limited, 1984.

Fig. 6

barrel of oil or its equivalent of gas in the United States was $ 14 for 1981 and 1982, and $ 16.50 in 1982, whereas in the rest of the world the corresponding figures were respectively $ 10 and $ 13.50, or 20 to 30 percent lower. By comparison, the Manager of Petrobras indicated that the discovery and development cost in Brazil in 1983 was $ 6 to $ 7 per barrel, broken down into $ 3 per barrel onshore and $ 10 to $ 12 per barrel offshore. The same cost in Angola was $ 4 to $ 5, according to the Exploration Manager of the national company Sonangol.

2.5. *Why* is there this disfavor of oil companies for the developing countries which have such promising possibilities, coupled with their excessive attraction toward the depleted subsoil of the United States? The job of these companies is to renew their reserves under the easiest and most profitable conditions. Yet whereas there is less and more expensive oil to be found, to be developed and to be produced in the industrialized countries, the tax situation is much more liberal and the end profitability from investments is much greater. Between an average net profit of $ 1 per barrel in the Third World and $ 5 to $ 6 in the United States, the choice is an easy one for a company to the extent that the chances of making a discovery in the United States are not ridiculously low.

Many developing countries have not yet woken up to the awareness that the situation has heen entirely upset since 1980. Today there is an oil glut that will last for some years. The risk of an oil crisis seems to have faded. Tbe actual selling price of oil has decreased in the last two years, whereas the costs of discovery, development and production have practically tripled. The tax conditions in the Middle East, which inspired their legislation some ten or fifteen years ago, are now much too severe for small and expensive fields.

In many cases as well, mining legislation has become too strict. The time-limit allowed for prospecting is too short, and the areas to be handed back quickly are too large. Another serious obstacle concerns the repatriation by the company of its contractual share of the profits. The lack of hard currency and the need to huy imported equipment often pressure governments to delay or prevent the company from repatriating its share of the profits or to require that the company reinvest all or part of its share on the spot for petroleum prospection or other uses. Yet nature ignores political boundaries, and for a company to continue to live it must be able to make up for its losses in one country by profits in another. It will not step in where it fears to be caught in a trap the instant it makes a discovery.

It should also be borne in mind that, if oil companies do not go and work in certain countries, it is that, for reasons of principle, governments prefer to use their own national budgetary resources. Such cases are less and less frequent.

To echo experts who can hardly be suspected of harboring any hostility toward the Third World, it can be said along with F. Parra (April 1984) that "companies go and prospect in industrialized countries because they find oil there faster, because they can finance their projects more easily, because production is more profitable there, and because there is no need to beg to be able to play". Or again, as Abdul Razak Hussain, General Manager of the Kuwait Foreign Petroleum Exploration Company, said (Geneva, December 1982): "Conditions must be created that are sufficiently attractive for the investor . . . The expenditures made by industry will go where profitability is considered to be the greatest and not where there are the greatest possibilities of finding reserves . . . If the tax conditions have been borrowed at random from other countries, there is a real danger that they form quite different economic conditions for exploration and production".

The exceptionally favorable tax system combined with the rise in discovery costs in the United States has stirred up a wave of business mergers since the end of 1983, in an attempt to acquire reserves by way of corporate takeover bids. The takeover or attempted takeover of large independent companies by Texaco (Gulf), Mobil (Superinor) and Chevron (Getty), and of the minority share of Shell Oil by its European parent company have been the most noteworthy such operations. $ 30 to $ 35 billion have been borrowed from banks all over the world to finance these takeovers, which aim to seize control of reserves for a price of $ 5 to $ 8 per barrel according to experts, whereas the actual cost of discovering them amounts to about $ 16. This is what is called "drilling for oil on Wall Street".

Actually, what is being purchased is access to an exceptionally liberal tax system. Therefore, it can be said that the main goal of petroleum exploration activity in the world today often lies more in drilling into tax structures than into geological structures. One of the unfortunate results of this state of affairs is that a very large share of the gigantic sums devoted to the purchasing of businesses will not be used for producing oil.

In this race for investors' money, the British Government in turn decided in March 1983 to greatly soften taxation so that the secondary fields in the North Sea, which had been scorned until then, would be made to produce.

In the face of such competition, many developing countries have the asset of possessing much more interesting geological prospects, whereas the problem of oil companies today is to find promising areas to prospect. These countries can thus hope to attract oil companies without having to tender such high expectations of profits as those proposed by the industrialized countries. Furthermore, if we wonder about the causes of the disfavor businesses seem to have with regard to the Third World, we must admit that political instability, which has often been mentioned, actually plays only a secondary role compared to economic causes. A great many examples can be cited of joint ventures which have survived changes in régime during the last fifteen or twenty years because it was profitable to both parties to pursue their cooperation.

3. *What Can Be Done?*

3.1. In the more or less long range, it is advantageous for all countries involved, both present and future producers or consumers of oil, for the developing countries to increase their national production of fossil fuels and decrease their imports of oil. It is in the interest of all for the external accounts of these countries to enable them to play an active role in world trade and development.

The consuming countries as a whole would benefit from a situation where the oil supply remains abundant and diversified throughout the world, to stabilize world resources, to reduce the danger of sudden price rises or drops, and to prevent excessive dependency on production from the troubled area of the Arabo-Persian Gulf.

In the long run, this is also advantageous for the group of producing countries. New production sources in the OIDCs would prevent excessive increases in oil prices so as to encourage faster development of alternative energy sources, and this would limit the tensions now existing in the Third World between oil buying and selling countries. They would ensure a longer life for existing reserves at a time when it is becoming fully evident that the renewal of world reserves will be ever more long and costly, that the price of oil will resume its rise after 1990, and that consumption will increase for many more years to come, even if it must be increasingly limited to specific uses of oil.

3.2. To develop their oil, gas and coal resources, the developing countries have the outlet. What they are lacking is crews of engineers and technicians and sufficient capital. The production schedule proposed by the World Bank between now and 1995 would enable oil production by the OIDCs to increase by 80 Mt/year and that of gas by 88 Mt/year. The investments required for this increase, which would nevertheless maintain oil imports equal to 73 percent of consumption, would cost, excluding refining, $ 154 billion for oil ($ 15.4 billion per year) and $ 36 billion for gas ($ 4.6 billion per year) between 1982 and 1992, making a grand total of $ 200 billion ($ 20 billion per year). Investments for coal during the same period would be $ 82 billion ($ 8 billion per year).

3.3. To find the money, there are two possible methods. In the first one, the government would include the sums in its budget and pay businesses for the piecemeal supervision and execution of operations. This solution is a costly one. It takes financial means away from other equally urgent equipment expenditures. It is not practicable for small countries with low resources.

The second and most often utilized method is that of a joint venture between the government and an oil company. This joint venture may involve different ways of sharing the risk, the expenditures, the oil after its discovery and any eventual profits. The formula which is tending to spread the most, with different variants covered by a "risk contract", calls for the oil company to assume responsibility for the risk of exploration. The company is then remunerated with part of the oil discovered. The payback for exploration expenses and for the risk taken is given priority during the first years of production by a sum equal to two or three times the expenditures incurred. The company then receives a share of the profit which varies according to the size and profitability of the fields discovered.

If this formula is discussed clearly and equitably — the host country can seek the advice of experts from the industrialized countries and the Third World — it is the best solution. The oil company brings the capital and technology, takes the risk of exploration, and is involved in the success of the joint venture.

3.4. What can be done by the companies and governments of the industrialized countries, by oil exporting countries, by international agencies and by potential producing countries to speed up this mobilization of oil and gas resources?

3.4.1. The industrialized countries, their companies, their banks and their governments can obviously contribute a great deal because they are the ones who have the money, the technological know-how, the practice of industrial organizational methods and large commercial outlets.

The operating of the petroleum businesses and banks in these countries always obeys the rules of market economics, and contracts cannot be concluded unless the host countries accept these rules.

The possibilities of discovery offered by the Third World should induce companies to spend there a large share of their exploration budget if reasonably attractive tax and legal conditions are provided. The companies must also accept liberal formulas for training and work for the technical personnel of the host country, so that this latter can take over operations by itself in a few years and create or develop its own national petroleum industry. All these stipulations have been in practice for many years now in various countries.

The government of the industrialized country can lend its support to training efforts by helping to finance them or by accepting trainees. Little by little, the technology transfer, which could be looked at somewhat like a toolbox with instructions for use, appears as it really is, i.e. the training of teams of engineers, economists and technicians spread out over an entire generation. The petroleum companies now operating, and often brilliantly so, in the Third World — Petrobras in Brazil, Sonatrach in Algeria, NIOC in Iran, INOC in Iraq, EGPC in Egypt, ONGC in India — were created twenty or thirty years ago.

It is probable that the next twenty years will see the amplification of the technological support which these enterprises are beginning to give to the Third World.

3.4.2. The oil exporting countries may contribute effectively to the mobilization of the oil and gas resources of the Third World:

First of all by making use of the important role they play in supplying the market to maintain prices at a satisfactory level, without any sudden jumps up or down. This price must not rise too much so as not to ruin the importing countries. It must not collapse — for example by 25 to 30 percent compared to present prices — so that the production of expensive new oil such as is now being found becomes impossible. The producing countries by themselves cannot control the prices, but their assistance is indispensable.

Considering that present prices are legitimate and represent the true value of oil, the exporting countries have thus far refused to give a preferential price to the developing countries, as has been proposed at various times by Libya or Iraq. The exporting countries have partially compensated for rises by loans under favorable conditions to various friendly or particularly disadvantaged countries. It is difficult to draw up a balance sheet. What has thus been loaned to the importing countries of the Third World might represent 10 to 20 percent of the price rises.

The exporting countries participate only very marginally in the petroleum exploration of importing developing countries. "The only organization which has financed oil and gas predevelopment activities has been the OPEC Fund", declared its General Manager, Ibrahim Shiata, in December 1982, "and we have only done a very little to date". Two projects have been financed in Tanzania for a sum of $ 22 million.

The Kuwait Foreign Petroleum Company was created in 1981 and works solely on a commercial basis. In 1982/83 it acquired interests in the United States, Morocco, Oman and Indonesia as well as in the Investment Energy Development Corporation (IEDC), an international investment corporation based in Geneva.

To date, the exporting countries have not acted directly to encourage rival productions to those of OPEC. This attitude has been reinforced since 1981 by the surplus of production capacity. On the other hand, the OPEC countries are participating liberally in the financing of the World Bank, which is very active in the energy development of the Third World.

3.4.3. Among the international organizations, it is indeed the World Bank which since 1977 has been playing the most active role in the mobilization of the oil and gas resources of the Third World, after having vigorously helped out with electricity and coal development as well as with the development of already-discovered oil and gas fields. At the beginning of 1979, an oil exploration assistance procedure was created in the form of reimbursable loans to finance seismic prospecting operations and the initial wildcat drilling. The role of the World Bank is not to take the place of oil companies — it finances only about 25 percent of exploration/development projects — but to act as a catalyst for prospection. Its mere presence among the financial backers is a guarantee of the full execution in the eyes of the companies as well as a deterrent to the risk of abusive nationalization, and this facilitates their participation.

By the end of 1982 the World Bank had financed some 70 exploration or development projects totaling $ 3.5 billion in 45 countries. Its intention is to finance about a dozen projects each year, for a sum of some $ 1 billion, enabling the launching of projects worth a total of $ 4 billion. These expenditures are broken down so that 10 to 15 percent goes to promote exploration, 20 to 30 percent for the direct financing of geological-surveying and exploration projects in the poorest countries (by IDA), and 55 to 70 percent for the cofinancing of the development of fields already discovered. The World Bank places special emphasis on the development of gas.

However, oil and gas make up only one-third of the energy investment projects supported by the World Bank, and these projects in turn make up only one-fifth of all the projects supported by this international organization. Oil and gas thus account for only 5 percent of the total commitments by the World Bank. They are thus far from being a top-priority field. The reason for this is that the international community rightly considers that they normally fall under the responsibility of the petroleum companies.

One of the difficulties with the World Bank lies in its financing. The Government of the United States, without refusing to contribute its share, has been expressing reserves concerning the financing of exploration/production projects which some petroleum companies feel might compete with their own activities. The opposition in the United States was decisive in the failure of the project to create a subsidiary specializing in the mobilization of the energy resources of the Third World, a project which was launched in 1981 and for which a capital of $ 6 to 7 billion was planned.

In addition to the World Bank, the International Finance Corporation plays a modest role. It is considering investing $ 100 million between 1985 and 1989 ($ 20 million per year) in the form of highly dispersed commercial shares of 5 to 10 percent per project. Its procedures are lengthy.

Likewise, different projects for insurance funds against exploration risks, launched in the last two or three years and which have not yet panned out, are hardly any different when analyzed from petroleum-share-buying financial companies.

3.4.4. Finally, *the importing countries can mainly count on themselves* to develop their oil and gas potential by acting in such a way as to attract external public and private assistance for which their subsoil may give cause to hope. What can they do that might be more effective? The following suggestions are taken from the experience gained from oil and gas ventures in recent years.

a) First of all, to make a comprehensive and concrete evaluation of the amounts of energy that will be needed for survival and development, by sector of consumption and by energy source. Many organizations are competent to act as consultants in this field.

b) To make preliminary surveys of natural resources by geological and geophysical prospecting. This is not a very expensive investment, and it is one for which the IDA (International Development Association) can act in favor of the poorest developing countries.

c) To establish, in mining codes or typical contracts, conditions for permit durations, the areas to be relinquished and rules for the repatriation of profits in line with international practice.

d) To strictly respect contracts that have been signed, except out of evident necessity. The abuse of the pretext of new circumstances which are different from the initial circumstances (rebus sic stantibus) is one of the most effective ways to scare off investors.

e) To grant priority importance to in-depth personnel training extending over a good number of years, in cooperation with petroleum companies and training organizations in industrialized countries.

f) To encourage exploration for and use of natural gas as the best replacement for oil, whether the gas is discovered alone or associated with oil.

g) Lastly and above all, before anything else is done, to make sure that the tax system is such that investors will not automatically prefer to invest in an industrialized country. Many countries have revised their tax systems in recent years, and investors have returned. Such is the case with Brazil, Egypt, Argentina, Indonesia and very recently India. It might reportedly be the case of China following the disappointing results of exploration on the continental shelf.

The General Director of the National Office of Petroleum Prospection and Production of Morocco, Mohammed Douieb, at an international symposium organized in Brazil by the IEDC and Petrobras in April 1984, said that very strong encouragement will be given to the first investors who decide to prospect for oil in Morocco. Up to 1990, for example, there are plans to make prospectors tax exempt for five years, and with the tax on the oil produced during this period limited to a royalty of 5 percent. A similar principle is included in the latest Indian income tax act.

These changes actually stem from a quite simple philosophy: it is better to receive 85 percent of something than 95 percent of nothing at all, proposing to pay a petroleum enterprise $ 3 per barrel in case of discovery and having one's subsoil prospected rather than offering $ 1 and waiting for an investor. The Kuwaiti Minster for Economics and Petroleum, Ali Khalifa El Sabah, said provocatively in Geneva in December 1982: "It is better to be exploited and produce an income that can be used to develop your country than not to be exploited and run from one financial crisis to the next. This sounds terrible but it is the way good businessmen run their companies and I will venture that it is a good way to run a development program".

4. *Conclusion*

"Le Tiers Monde ne fait plus recette" (The Third World Is No Longer a Good Box Office Draw) ran a title one day in December 1983, in a report on the latest meeting of IDA highlighting its financing difficulties. It is true, and it is largely the consequence of the world economic crisis. The special situation of oil should, insofar as it is involved, enable too much discouragement to be avoided. All those who scan the future know that world economic growth will be back with us again soon, and with it the demand for oil will rise. U.S. resources are depleted. Soviet production is reaching its ceiling. The price of crude oil makes possible the extensive prospecting of the Third World. To ensure their supplies after 1990, the consuming countries have the choice between exploring the Third World or returning to excessive dependency on the Middle East. The leading preoccupation of all petroleum enterprises in the world today is that the Earth is so small that there is a great deal of difficulty in finding areas to prospect. The Third World countries offer great possibilities.

The developing countries should not be frightened by the fact that, for many years, oil has stopped being an issue of physical resources and become solely a problem of capital and money. It will be all the easier for them to keep the energy resources discovered in their subsoil for their own development, paying the enterprise the amount agreed upon with it, without any dispute over the destination of the production.

The most important reason to be hopeful today is finally that, between producing and consuming countries, there is today much better reciprocal understanding of the facts and economic mechanisms they are involved with, an awareness of the interdependence of their interests, and a multiplication of contacts among persons. It is extraordinarily comforting that for more than a year now, since March 1983, oil prices have not collapsed as they should have as the result of the glut, because the governments and companies of the leading oil producing and purchasing countries were aware that such a collapse would have been a catastrophe for everybody. Of course, there is still a lot to be done. Meetings such as this one organized by the Pontifical Academy, in the spirit of honesty and generosity, contribute powerfully to making this awareness broader and more universal. May the Academy, its President and ENEA receive the expression of our profound gratitude.

ENERGY AND DEVELOPMENT: FOSSIL FUELS IN DEVELOPING COUNTRIES

NAZLI CHOUCRI
Professor of Political Science
Associate Director, Technology Adaptation Program
Massachusetts Institute of Technology
Cambridge, U.S.A.

1. Introduction

The developing states are a very diverse group — with great variation in population size, level of economic activity, resource endowments, and energy profile. Despite their differences, every developing state has a modern sector that relies on commercial fuels. In contrast to industrial societies, however, traditional sources of energy are also used extensively. This paper focuses on one major source of energy — fossil fuels — and highlights some critical policy issues. Developing countries are confronted with a crowded policy agenda, which makes a focus on energy difficult, yet critical.

Energy use everywhere is tied to population growth, industrialization, expansion of urban centers, and development of industrial and infrastructural facilities. For developing countries the most immediate consequences of oil price changes in the decade of the 1970s have commonly been seen in terms of the import bill and attendant needs for borrowing from international institutions or commercial markets. Adjustments of economic targets were set in place, as were a reassessment of priorities, involving reappraisal of investment strategies and infrastructure development. The potential for expanding alternative energy sources and exploiting indigenous resources in both conventional and nonconventional forms is now being examined, as are new responses to the constraints imposed by the world oil market of the early 1980s.

Changes in energy prices and availability have strongly affected public policy in developing countries. The energy situation has influenced economic performance and provided new constraints for government policy. Now developing countries must take into account the energy dimension of any major investment or public policy. Yet in those societies, as in industrial states, nothing of substance can be done without explicit recognition of the limits of social, political, and economic parameters. In countries where development planning has become a tradition, the use of government machinery for public sector enterprises constitutes an essential corollary of planning programs.

The impact of changes in oil prices on the balance of payments of developing countries is well documented and, together with statistical estimates of impacts on growth, provides the picture we have of these countries' energy problems. Beyond that, however, many of the insights on energy and development come from existing analyses of industrial economies with the implicit expectation that the developing states may follow a well known path of industrialization.

Clearly, changes in prices or availability of energy already have had distinctive macroeconomic effects for all countries, developed as well as developing. This is especially true for countries that are high users of petroleum and do not have readily available substitutes, or cannot easily make adjustments in demand in response to change in prices or quantities. The process of development itself is deeply affected by energy inputs.

Between 1974 and 1978, combined economic shocks upon the developing world (in terms of oil prices, inflation, reduced growth, loss of export market) were varied in their impacts. On the average, the oil importing developing state lost about 2 percent of their GDP. The rapidly industrializing group, also oil importers (Brazil, Hong Kong, South Korea, Philippines, and Turkey) lost 1.8 percent of GDP. The large South Asian oil importing countries lost about 2 percent, and the poorest of the developing countries witnessed a 1.5 percent loss in GDP.(1) These figures must be viewed in the dual context of productivity foregone as well as population growth.

The full effects of the energy parameters on policy planning in developing countries are not yet known. There is little specific information on the impact of energy on sectoral performance. Even less information is available about long-term effects of policies designed to

(1) Economist Intelligence Unit, Nr. 125, *Oil Imports of Developing Countries* (London: Economist Intelligence Unit, 1982), pp. 23-24.

alleviate immediate strains, or impacts of longer-term policies designed to reorient development strategies.

In its most fundamental guise development in itself entails four distinct but inter-related processes that lead to improvements in human conditions. These are: (1) economic growth, in terms of greater productivity and increasing overall national output; (2) structural change, in terms of transformations in employment patterns, distribution of economic activity, rates of urbanization, and overall industrialization; (3) social equity and welfare, in terms of the allocation of resources and attention to social services, education, health, and other aspects of social well-being; and (4) institutional development, in terms of the establishment of government agencies to allocate and manage resources for development.(2) These processes reflect the complexity and comprehensive nature of development. Energy variables play an important role in each of these four dimensions of development, although it is clear that we still need to determine precisely *how* and *how much*.

One common underlying objective for most developing countries is to exercise national autonomy in decision-making: the ability to make decisions in areas of national policy without outside interference. This concern generally means exercising greater self-reliance and autonomy in making decisions of national importance. Thus, in all developing countries, the search for national autonomy has emerged as a driving force in public policy debates. This drive is also becoming evident in the energy sector. While the search for autonomy has guided both the nature and the content of development planning, for many states effective autonomy is not possible in any sphere of activity, and least of all in energy. This reality thus necessitates international cooperation and collaboration.

The following section highlights the great variation among countries at different levels of industrialization, not only in population, size, and economic activity, but especially in terms of energy dependency. The countries we consider include the semi-industrialized states (such as Brazil, Korea, Taiwan), the industrializing states (such as Mexico, Egypt, Tunisia, Portugal, and Turkey), as well as the least developed (Sudan, Zaire, and others).

(2) Nazli Choucri, *Energy and Development in Latin America: Perspectives for Public Policy* (Lexington, Mass.: D.C. Heath/Lexington Books, 1982).

2. Diversity in Development

2.1 *Population*

While it is customary to consider industrializing countries as one homogeneous group, the fact remains that there is an enormous diversity among them. This diversity makes simple generalizations particularly misleading. On demographic grounds alone, the variation is impressive. Four countries have populations of 100 million or more, while over 50 countries register populations of under 20 million (see Table 2-1).

2.2 *Economic Activity*

On a per capita GNP basis, the distribution is less skewed and the four population giants lose some of their prominence. Over 20 countries are in the high income group, with $1000 per capita or more. The low income group of $ 500 or less per head is somewhat smaller in size (see Table 2-2). Many of the highest income states are also among those growing at the fastest rates, of 7 percent a year or more (see Table 2-3). Then there are over 10 countries that claim an industrial component of 40 percent share of total GNP. The majority of the states are in the « medium » range, with an industrial sector of 25-40 percent of GDP (see Table 2-4).

2.3 *External Debt*

The foreign debt issue is perbaps one of the most critical problems facing the developing world. Even then, however, despite massive financial claims of the external environment, close to 30 countries have « low » debts of 20 percent or less relative to GDP. Conversely, however, there are 12 extremely critical cases whose GDP is almost entirely mortgaged to external creditors. The difficulty, of course, is that such comparisons hide the idiosyncrasies of individual cases: the massive debt of several Latin American countries pales relative to the size of the GDP, while much smaller debts of other states loom large relative to total economic output (see Table 2-5).

2.4 *Energy Dependency*

We turn to one central aspect of their energy profile: the dependency issue. (Other aspects are examined in subsequent sections of this

TABLE 2-1 - *Variation in Population Size.*

High (*100 million or more*)	High Medium (*50-100 million*)	Low Medium (*20-50 million*)	Low (*under 20 million*)
Brazil	Bangladesh	Argentina	Algeria
China	Mexico	Colombia	Angola
India	Nigeria	Egypt	Benin
Indonesia	Pakistan	Ethiopia	Bolivia
		Korea	Burundi
		Morocco	Cameroon
		Philippines	Chile
		Thailand	Congo
		Turkey	Costa Rica
		Yugoslavia	Dominican Republic
		Zaire	Ecuador
			El Salvador
			Gabon
			Ghana
			Greece
			Guatemala
			Haiti
			Honduras
			Hong Kong
			Iraq
			Ivory Coast
			Jamaica
			Kenya
			Malawi
			Malaysia
			Mozambique
			Nepal
			Nicaragua
			Niger
			Panama
			Papua New Guinea
			Paraguay
			Peru
			Portugal
			Rwanda
			Senegal
			Sierra Leone
			Singapore
			Somalia
			Sri Lanka
			Sudan
			Tanzania
			Trinidad and Tobago
			Tunisia
			Uganda
			Uruguay
			Venezuela
			Zambia
			Zimbabwe

Source: World Bank, *The Energy Transition in Developing Countries* (Washington, D.C.: World Bank, 1983), Appendix.

TABLE 2-2 - *Variation in Per Capita GNP.*

High (*$1000 per capita or more*)	Medium (*$500-$1000 per capita*)	Low (*$500 per capita or less*)
Algeria	Bolivia	Bangladesh
Argentina	Cameroon	Benin
Brazil	Congo	Burundi
Chile	Egypt	China
Colombia	El Salvador	Ethiopia
Costa Rica	Honduras	Ghana
Dominican Republic	Mozambique	Haiti
Ecuador	Nicaragua	India
Gabon	Nigeria	Indonesia
Greece	Papua New Guinea	Kenya
Guatemala	Philippines	Malawi
Hong Kong	Thailand	Nepal
Ivory Coast	Zambia	Niger
Jamaica	Zimbabwe	Pakistan
Korea		Rwanda
Malaysia		Senegal
Mexico		Sierra Leone
Panama		Somalia
Paraguay		Sri Lanka
Peru		Sudan
Portugal		Tanzania
Singapore		Uganda
Trinidad		Zaire
Tunisia		
Turkey		
Uruguay		
Venezuela		
Yugoslavia		

Source: World Bank, *The Energy Transition in Developing Countries* (Washington, D.C.: World Bank, 1983), Appendix.

TABLE 2-3 - *Variation in GNP Growth Rates.*

High *(7 percent or more)*	Medium *(4.0-7.0 percent)*	Low *(4.0 percent or less)*
Algeria	Bolivia	Argentina
Brazil	Cameroon	Bangladesh
Ecuador	China	Benin
Egypt	Colombia	Burundi
Hong Kong	Congo	Chile
Indonesia	Costa Rica	Ethiopia
Iran	Dominican Republic	Ghana
Iraq	El Salvador	Haiti
Korea	Gabon	India
Malaysia	Greece	Jamaica
Paraguay	Guatemala	Mozambique
Singapore	Honduras	Nepal
Thailand	Ivory Coast	Nicaragua
Tunisia	Kenya	Niger
	Malawi	Papua New Guinea
	Mexico	Peru
	Morocco	Senegal
	Nigeria	Sierra Leone
	Pakistan	Somalia
	Panama	Uganda
	Philippines	Uruguay
	Portugal	Zaire
	Rwanda	Zambia
	Sri Lanka	Zimbabwe
	Sudan	
	Tanzania	
	Trinidad and Tobago	
	Turkey	
	Venezuela	
	Yugoslavia	

Source: World Bank, *The Energy Transition in Developing Countries* (Washington, D.C.: World Bank, 1983), Appendix.

TABLE 2-4 - *Variation in Levels of Industrialization.*

High *(40 percent of GDP or more)*	Medium *(25-40 percent of GDP)*	Low *(25 percent or less of GDP)*
Algeria	Argentina	Bangladesh
China	Bolivia	Benin
Congo	Brazil	Burundi
Gabon	Chile	Cameroon
Indonesia	Colombia	El Salvador
Iran	Costa Rica	Ethiopia
Iraq	Dominican Republic	Ghana
Korea	Ecuador	Ivory Coast
Nigeria	Egypt	India
Peru	Greece	Kenya
Portugal	Honduras	Malawi
Trinidad and Tobago	Hong Kong	Mozambique
Venezuela	India	Nepal
Yugoslavia	Jamaica	Rwanda
	Malaysia	Sierra Leone
	Mexico	Somalia
	Morocco	Sudan
	Nicaragua	Tanzania
	Niger	Uganda
	Pakistan	
	Papua New Guinea	
	Paraguay	
	Philippines	
	Senegal	
	Singapore	
	Sri Lanka	
	Thailand	
	Tanzania	
	Tunisia	
	Turkey	
	Uruguay	
	Zaire	
	Zambia	
	Zimbabwe	

Source: World Bank, *The Energy Transition in Developing Countries* (Washington, D.C.: World Bank, 1983), Appendix.

TABLE 2-5 - *External Public Debt 1981.*

Low *(20 percent of GNP or less)*	Medium *(20-50 percent of GNP)*	High *(50-100 percent of GNP)*
Argentina	Algeria	Benin
Brazil	Bangladesh	Congo
Chile	Bolivia	Costa Rica
Colombia	Cameroon	Ivory Coast
Dominican Republic	Ecuador	Jamaica
El Salvador	Egypt	Morocco
Ethiopia	Haiti	Nicaragua
Ghana	Honduras	Panama
Greece	Kenya	Somalia
Guatemala	Korea	Sudan
Hong Kong	Malawi	Zaire
India	Niger	Zambia
Indonesia	Pakistan	
Malaysia	Papua New Guinea	
Mexico	Peru	
Nepal	Portugal	
Nigeria	Senegal	
Paraguay	Sierra Leone	
Philippines	Sri Lanka	
Rwanda	Tanzania	
Singapore	Tunisia	
Thailand	Turkey	
Trinidad and Tobago		
Uganda		
Uruguay		
Venezuela		
Yugoslavia		
Zimbabwe		

Source: *World Development Report 1983* (Oxford University Press for the World Bank, 1983).

paper). Table 2-6 ranks the developing states in terms of « self-sufficiency », domestic production in relation to total consumption of commercial energy. Here the variation among them is extensive and their respective policy agendas are shaped accordingly.

Excluding the oil-rich countries with low populations — Saudi Arabia, Kuwait, the United Arab Emirates, and Libya — there are 19 developing countries that are *self-sufficient* in commercial energy, and of these only seven are OPEC members.

Among the notable self-sufficient exporters are Mexico and Egypt, two countries whose energy profile combined with their demographic and economic profiles highlights the "typical" problems of this group: (1) expanding domestic consumption due to industrialization, and government policies subsidizing domestic energy prices; (2) a robust petroleum and natural gas industry whose performance depends on the world oil market; and (3) a national oil company regulating this sector. In the case of Egypt investments in exploration and development are governed by production sharing agreements with foreign oil companies. For Mexico, the government and the public sector enterprises make the investments.

These two states highlight the dilemmas and opportunities for fossil fuel management in developing states. Domestic pricing policies are needed to rationalize consumption; and substantial investments are needed to expand production capacity in the expectation that international market conditions might change and then require greater production from these two states (if existing capacity permits). Finally, both countries illustrate the potential perils of extensive reliance on a petroleum export market.

The five *nearly self-sufficient* states, in Table 2-6, are very diverse. India, Argentina, and Colombia share an economic and energy profile that is highly "advanced" relative to Zaire and Zimbabwe, with considerably greater scope for energy diversification.

The *less dependent* group includes states as varied as Brazil, which has made notable experiments in alcohol fuel, and Turkey, whose geology precludes ready expansion of a petroleum sector.

The *dependent states* all share the typical problems of developing countries. Of the 33 countries in Table 2-6 only five (Portugal, Singapore, Hong Kong, Greece, and Korea) stand out as semi-industrial and relatively unburdened economically by their highly energy-dependent profile.

This diversity in energy profile obscures the fact that in *all* the developing countries (from the least to the most industrialized) consump-

TABLE 2-6 - *Self-Sufficiency Ratios of Total Commercial Energy (Production as Percentage of Consumption).*

Self-Sufficient (Exporters)		*Nearly Self-Sufficient*		*Less Dependent*		*Dependent*	
Iraq	1210	Zaire	98	Pakistan	68	Nepal	35
Nigeria	1059	Colombia	90	Zambia	68	Honduras	33
Congo	630	Zimbabwe	87	Yugoslavia	64	Malawi	32
Gabon	601	Argentina	86	Chile	63	Burundi	31
Angola	588	India	79	Ghana	59	Uganda	31
Algeria	575			Rwanda	48	El Salvador	31
Venezuela	391			Turkey	48	Ivory Coast	25
Cameroon	351			Brazil	48	Greece	24
Indonesia	350			Bangladesh	44	Korea	24
Ecuador	277			Costa Rica	42	Tanzania	23
Iran	250			Mozambique	41	Uruguay	22
Trinidad and Tobago	266			Paraguay	41	Portugal	22
Tunisia	215					Morocco	21
Egypt	196					Ethiopia	20
Bolivia	195					Haiti	20
Malaysia	181					Sri Lanka	18
Mexico	162					Philippines	17
Peru	133					Nicaragua	16
China	105					Papua New Guinea	14
						Benin	13
						Sudan	12
						Panama	10
						Niger	10
						Kenya	10
						Guatemala	10
						Thailand	6
						Dominican Republic	—
						Jamaica	—
						Hong Kong	—
						Senegal	—
						Sierra Leone	—
						Singapore	—
						Somalia	—

Total for all 69 countries: 125 percent.

Source: World Bank, *The Energy Transition in Developing Countries* (Washington, D.C.: World Bank, 1983), Appendix.

tion of commercial energy has been growing rapidly. The demand for liquid fuels takes the lead, and pressure on petroleum uses are particularly acute. In Egypt, for example, domestic consumption has been growing at 10 percent per year over the past decade. Thus, the demand side of the equation bears scrutiny, as does supply expansion potential. On both sides of the energy equation there is extensive scope for adjustment and change. It bears stressing that in the ten years since the initial oil price increases of 1973, there have been tremendous changes in both demand and supply.

2.5 *The Energy Imperative*

The pattern of industrialization in the West has provided the model for anticipated growth in the industrializing world. The near perfect positive correlation between energy consumption and GDP, so famous for industrial countries, appears to be replicated for the developing world as well. Figure 2-1 shows the relationship between energy use and GDP (on a per capita basis). The countries indicated in this figure are a subsample of the tables discussed so far. Even then, we see the strong connections between energy and GDP.

The relationship between energy consumption and industry as a share of GDP is shown in Figure 2-2. There the connection is also apparent, but with less strength in patterns than in Figure 2-1.

Finally, we turn to the population factor, the relationship between population size and energy consumption. The near-linear scatter in Figure 2-3 shows the role of numbers in shaping the demand for energy. The level of total economic output is, however, a more important factor.

These three figures illustrate the basic dilemma inherent in growth: industrialization plus added population invariably results in greater energy consumption. This conclusion summarizes the past and the present. It does not necessarily define the future. Energy management is becoming imperative everywhere, and in conjunction with technological change, provides the basis for future patterns of energy consumption and of growth.

The following section of this paper looks at the demand side, with particular emphasis on macroeconomic effects of changing domestic energy prices.

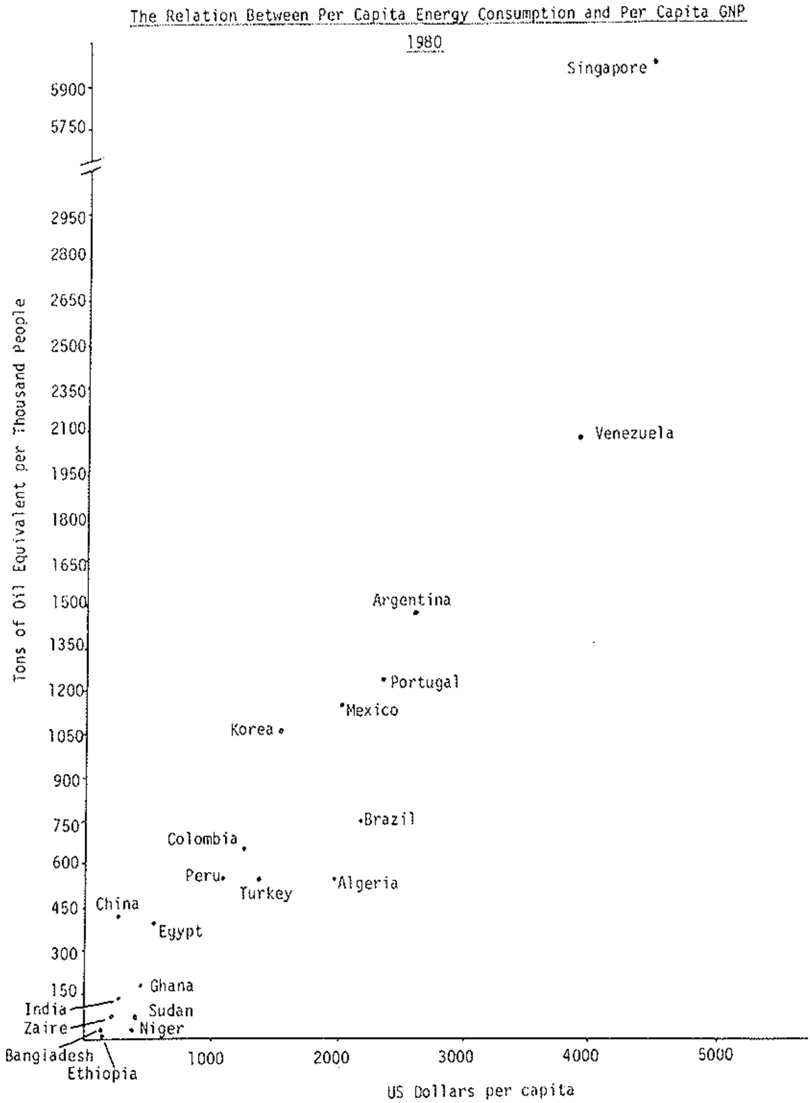

The Relation Between Per Capita Energy Consumption and Per Capita GNP
1980
Singapore
Venezuela
Argentina
Portugal
Mexico
Korea
Brazil
Colombia
Peru
Turkey
Algeria
China
Egypt
Ghana
India
Sudan
Zaire
Niger
Bangladesh
Ethiopia
5900
5750
2950
2800
2650
2500
2350
2100
1950
1800
1650
1500
1350
1200
1050
900
750
600
450
300
150
1000
2000
3000
4000
5000
Tons of Oil Equivalent per Thousand People
US Dollars per capita

FIG. 2-1

The Relation Between Energy Consumption and Industry as a Percentage of G

1980

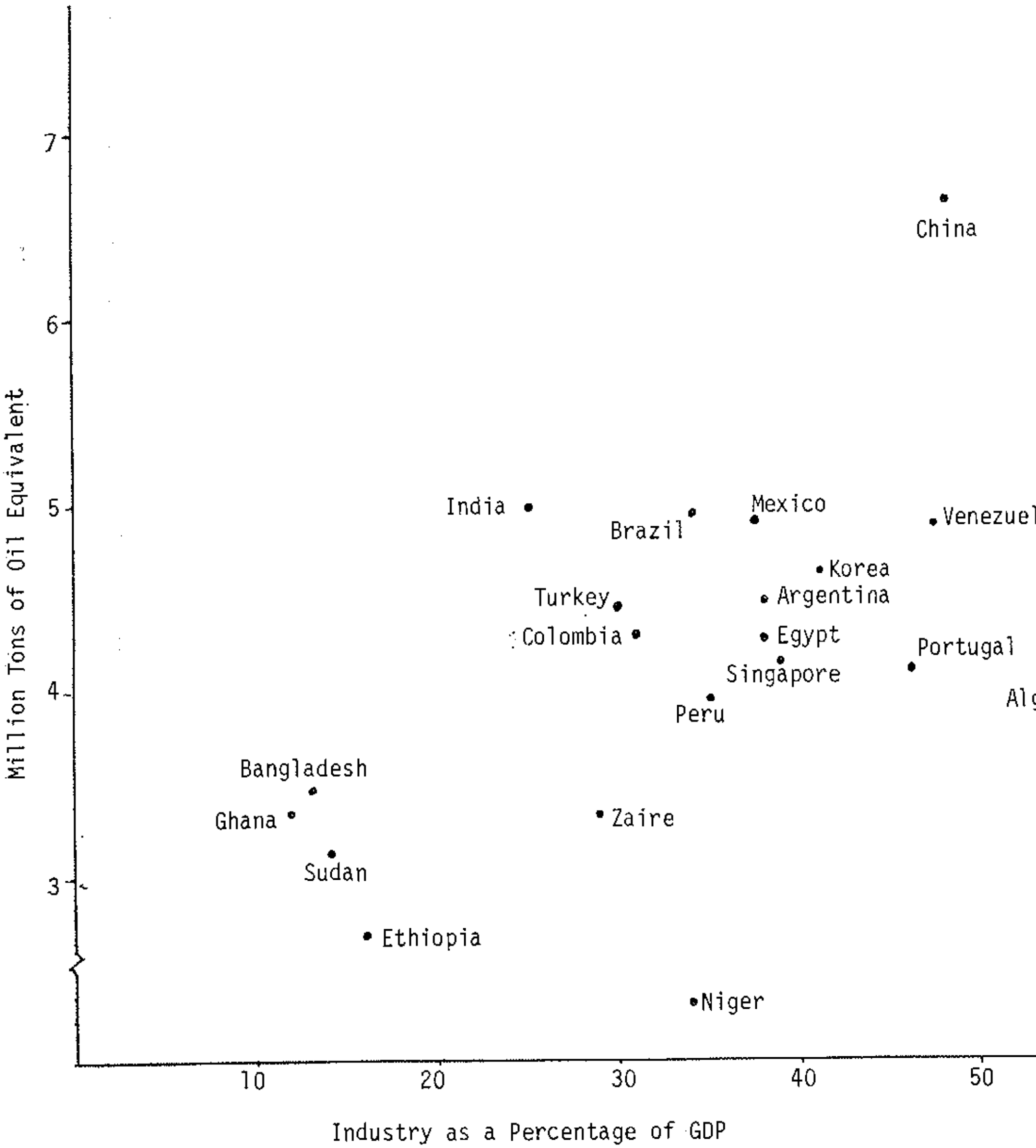


FIG. 2-2

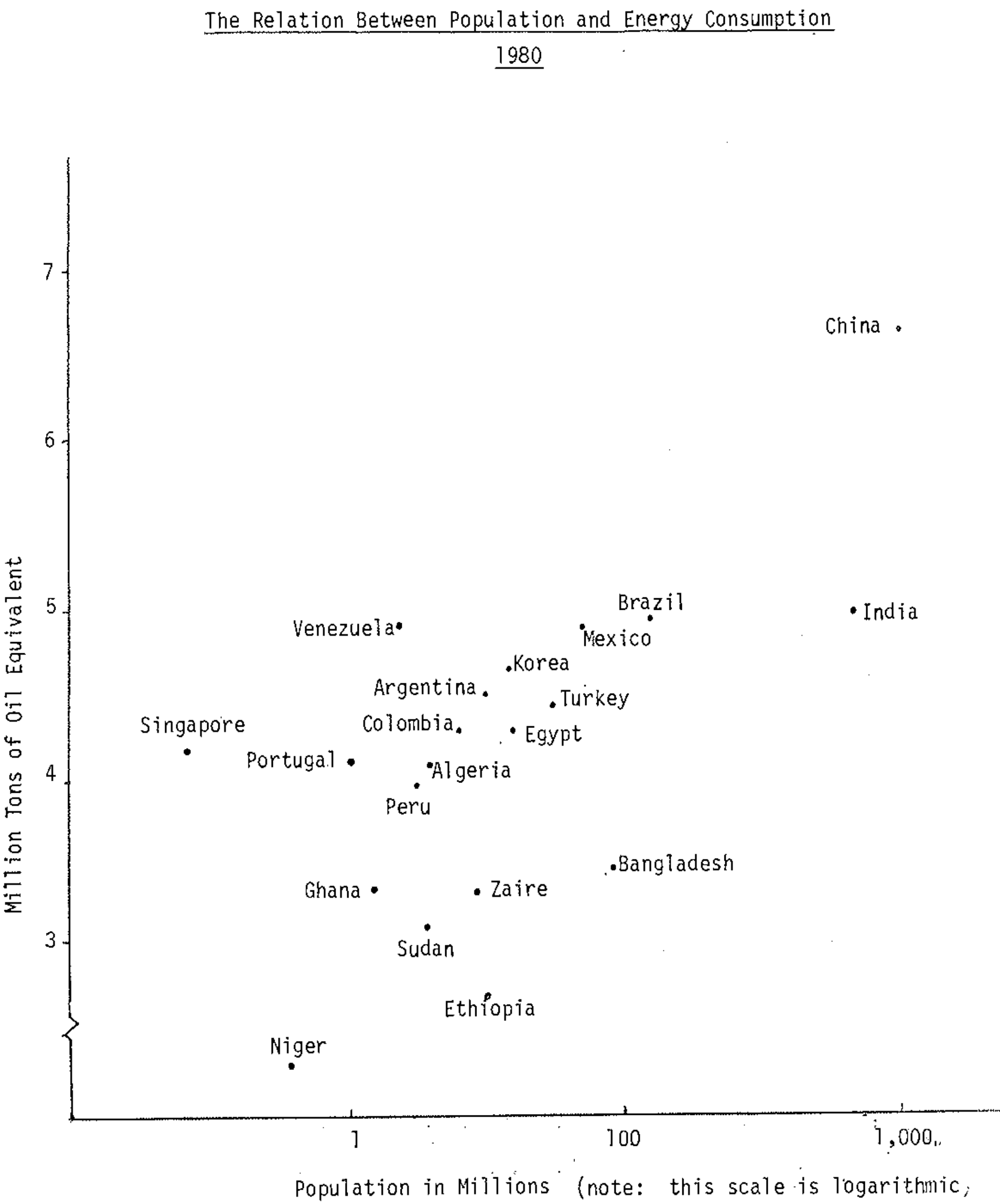

The Relation Between Population and Energy Consumption
1980
Million Tons of Oil Equivalent
7
6
5
4
3
China
India
Brazil
Mexico
Venezuela
Korea
Argentina
Turkey
Singapore
Colombia
Egypt
Portugal
Algeria
Peru
Bangladesh
Ghana
Zaire
Sudan
Ethiopia
Niger
1
100
1,000
Population in Millions (note: this scale is logarithmic)

FIG. 2-3

3. The Demand Side

The consumption of commercial energy in developing countries has grown rapidly, at an average rate of 7.9 percent per annum from 1955 to 1978, compared to 3.8 percent for the industrial states. Oil in many cases accounts for 80 percent of total commercial energy consumption.(3) The World Bank estimates that the growth in commercial energy demand will be 4.5 percent from 1980 to 1995, with the percentage share of oil dropping from 47 to 36 percent.(4) Table 3-1 shows the energy consumption per 1000 population for the developing states, grouped on this basis by high, medium, and low consumption.

The per capita energy consumption obscures another dimension of demand, namely energy use in terms of oil equivalent per million US dollars of GDP. This indicator shows the energy intensity of economic activity, with high users consuming 500 tons of oil equivalents for every million US dollars of GDP. Only 14 countries demonstrate low energy intensity, in contrast to the 26 countries that demonstrate low per capita energy use. See Table 3-2.

3.1 *The Giants*

Again, aggregate figures simply distort the picture: these figures are shaped by four countries. China alone accounts for 30 percent of total commercial energy demand for developing states and 60 percent of their coal demand; Brazil, Mexico, India account for an additional 20 percent. A total of 12 countries consume more than two-thirds of all commercial energy in developing countries. Thus, if we exclude the largely coal-based consumption patterns of China and India, oil accounts for 61 percent of all commercial energy consumption of developing countries in 1980. The World Bank estimates a decline in oil utilization to 44 percent of all commercial use by 1995.

For oil-importing developing countries, 25 percent of the increase in commercial energy demand is expected to be met by an increase in oil consumption in the period 1980-1995. Net oil imports are expected to decline from 44 percent of total commercial energy consumption to 28

(3) Joy Dunderley et al., *Energies Strategies for Developing Nations* (Washington, D.C.: Resources for the Future 1980), p. 9.

(4) World Bank, *The Energy Transition in Developing Countries* (Washington, D.C.: World Bank, 1983), p. 5.

TABLE 3-1 - *Energy Consumption (tons of oil equivalent per 1,000 people).*

High *(500 toe or More)*	Medium *(200-500 toe)*	Low *(200 toe or Less)*
Algeria	Bolivia	Angola
Argentina	China	Bangladesh
Brazil	Congo, P.R.	Benin
Chile	Dominican Rep.	Burundi
Colombia	Ecuador	Cameroon
Costa Rica	Egypt	Ethiopia
Gabon	El Salvador	Ghana
Greece	Guatemala	Haiti
Hong Kong	Honduras	India
Iran	Morocco	Indonesia
Iraq	Nicaragua	Ivory Coast
Jamaica	Papua New G.	Kenya
Korea	Paraguay	Malawi
Malaysia	Philippines	Mozambique
Mexico	Senegal	Nepal
Panama	Thailand	Niger
Peru		Nigeria
Portugal		Pakistan
Singapore		Rwanda
Trinidad and Tobago		Sierra Leone
Turkey		Somalia
Uruguay		Sri Lanka
Venezuela		Sudan
Yugoslavia		Tanzania
Zambia		Uganda
Zimbabwe		Zaire

Source: Based on World Bank, *The Energy Transition in Developing Countries* (Washington, D.C.: World Bank, 1983), Appendix.

TABLE 3-2 - *Energy Consumption (tons of oil equivalent per million US dollars of GDP).*

High (*500 toe or more*)	Medium (*200-500 toe*)	Low (*200 toe or Less*)
Colombia	Algeria	Benin
Egypt	Argentina	Burundi
Indonesia	Bangladesh	Cameroon
Korea	Bolivia	Ethiopia
Pakistan	Brazil	Ghana
Panama	Chile	Guatemala
Portugal	Congo, P.R.	Ivory Coast
Senegal	Costa Rica	Malawi
Singapore	Dominican Rep.	Nepal
Sri Lanka	Ecuador	Niger
Trinidad and Tobago	El Salvador	Nigeria
Venezuela	Gabon	Paraguay
Yugoslavia	Greece	Rwanda
Zambia	Haiti	Sudan
Zimbabwe	Honduras	Tanzania
	Hong Kong	
	Indonesia	
	Iraq	
	Kenya	
	Malaysia	
	Mexico	
	Morocco	
	Mozambique	
	Nicaragua	
	Papua New G.	
	Peru	
	Philippines	
	Sierra Leone	
	Somalia	
	Thailand	
	Tunisia	
	Turkey	
	Uruguay	
	Zaire	

Source: Based on World Bank, *The Energy Transition in Developing Countries* (Washington, D.C.: World Bank, 1983), Appendix.

percent by 1995.(5) Again, these aggregate figures hide the fact that over half of all oil-importing developing states rely on external sources for well over 75 percent of their commercial energy requirements.

3.2 *Sectoral Consumption*

A detailed sectoral breakdown for commercial energy use in developing countries is not available, although it is clear that transportation and industry are major consumers. For example, the World Bank estimates that transportation consumes between 20 and 40 percent of all oil use in developing countries, with 65-80 percent by road vehicles, of which 60 to 80 percent is by trucks.(6) The Economist Intelligence Unit estimates that of total commercial energy, 15-30 percent in mid-income and 10-20 percent in low income countries is consumed in the transportation sector, with 70-85 percent consumed by road vehicles, 5-10 percent by airplanes, and 3 percent by trains.(7) Industry is estimated to consume 35 percent of total commercial energy, and its share of energy use is rising faster than any other sector. Dependence on oil or indeed any other commercial fuel is low in the residential sector — between 10 and 20 percent of the total, most of it in electricity. Finally, the agricultural sector consumes about 20 percent of all commercial energy.

The fact that both economic growth and total demand of energy in developing countries are growing faster than for the developed states points to a critical dilemma: growth by necessity entails greater energy consumption. See Figure 2-1. Thus, from 1980 to 1995, the World Bank forecasts that the developing states' share will rise from 20 to 25 percent of world total. Two factors are responsible for the dilemma: higher rates of population growth (about three times higher than in industrial states) and lower price elasticities of demand (due, to some extent, to government subsidy policies). Moreover, the demand for commercial energy will rise faster than the demand for traditional energy as economies expand their modern sectors with the concomitant industrialization and urbanization patterns.

(5) World Bank (1983), pp. 5-6.
(6) World Bank (1983), pp. 19-20.
(7) Economist Intelligence Unit, Nr. 132, *Petroleum Investment in Developing Countries* (London: Economist Intelligence Unit, 1982), p. 4.

3.3 *Energy Imports*

The size of the oil import bill has been burdensome for almost every developing state. The imports of fuels for non-OPEC developing countries (excluding China) rose from 12 to 23 percent from 1973 to 1977 as a percentage of total imports.

In 1979 net oil imports represented between 8 and 14 percent of total imports in most non-oil exporting countries, but for 10 out of 61 countries (including Brazil, India, Turkey, Philippines, Thailand) oil imports represented over 20 percent of total imports. In the same year, nine countries had net oil imports equalling 5 percent of GNP or more, while in Cuba, Taiwan, Jamaica, Lebanon, Liberia, Jordan, Mauritania, Nicaragua, and Sudan the combination of rising oil prices and a stronger dollar meant that oil import payments represented more than 10 percent of GNP.

Net oil imports of all non-oil exporting countries increased from $ 19 billion in 1978 to $ 45 billion in 1981, a rise of 136 percent. Current account deficits rose from $11.6 billion in 1973 to $69 billion in 1981 in constant 1978 dollars. For low-income countries the deficit rose from 2.4 percent of GNP to 4.6 percent and for middle income countries the deficit rose from 1 percent to 6.1 percent in the same period. Brazil, Hong Kong, India, Pakistan, South Korea, Taiwan, and Thailand accounted for 80 percent of non-oil economies' imports of oil and 60 percent of the $69 billion 1981 current account deficit.([8])

The burden of energy imports is indicated in terms of energy imports as a percentage of total imports in Table 3-3. For ten countries, oil imports are 25 percent or more of their total import bill, while 25 countries show an energy bill of 10-25 percent of their total imports. For eight countries the import bill, and attendant burdens, are low despite the fact that several of them are highly dependent on external sources of energy.

Despite these figures and the estimates of GNP foregone noted earlier, it is important to stress that growth has not been as adversely affected by the oil imports bill as had been feared in the early 1970s. One decade after the events of 1973, we can observe that the developing states have fared rather well. Indeed, in Latin America, for example, there is no observable decline in the role of the transport sector as a

([8]) Based on a discussion in Economist Intelligence Unit, Nr. 125 (1982), pp. 20-30.

TABLE 3-3 - *Energy Importers.*

High *(25% of Total Imports or more)*	Medium *(10-25% of Total Imports)*	Low *(10% of Total Imports or Less)*
Brazil	Bangladesh	Argentina
Dominican Rep.	Chile	Benin
Hong Kong	Colombia	Burundi
Korea	Costa Rica	Hong Kong
Panama	El Salvador	Mozambique
Philippines	Ethiopia	Singapore
Thailand	Ghana	Somalia
Turkey	Greece	Zaire
Uruguay	Guatemala	
	Honduras	
	Ivory Coast	
	Kenya	
	Malawi	
	Morocco	
	Nepal	
	Pakistan	
	Paraguay	
	Portugal	
	Senegal	
	Sri Lanka	
	Sudan	
	Tanzania	
	Yugoslavia	
	Zambia	

Source: Based on World Bank, *The Energy Transition in Developing Countries* (Washington, D.C.: World Bank, 1983), Appendix.

share of GDP. As transport is a major user of energy, this fact is of considerable significance.(9)

3.4 *Demand Management*

In the developing world there exists scope for both conservation and substitution, the two sides of demand management. Conservation strategies have been pursued actively and relatively successfully in Brazil, China, and South Korea, while substitution efforts have already been undertaken in Bangladesh, Bolivia, and Pakistan (to gas), Zambia (to coal), and Mauritius (to bagasse). Yet industrial plants continue to be inefficient compared to the international standards. In some developing states about 10 to 30 percent of energy is consumed per unit of output; in others, even more energy is used.(10)

Viable demand management strategies are tied to sectoral uses of energy. For example, the role of energy is especially critical in the transportation sector, a high energy user in all types of economics, where the impact of higher oil prices has been immediate. The transport sector's hold on the entire process of development may well be deeply circumscribed by new scarcities, in both the general economy and among individual sectors, providing new sets of problems for government and new concerns for public policy. The transport sector holds an important key to future change in patterns of energy use. Given the transportation sector's large share of petroleum consumption, transport-specific energy policies are particularly necessary.(11)

Renovation of industrial capital in many developing states has shown that there is scope for significant improvements in the efficient use of energy, particularly in industry, as the construction of plants coming on line can incorporate technological innovations for reduced energy use. There is, further, a range of low cost investments with paybacks over 10-20 months. Paybacks of larger conversions and investments in more

(9) Choucri (1982). I am grateful to Fernando Bustamente for pointing out this unusual factor.

(10) World Bank (1983), p. 14.

(11) These entail better and more regular maintenance of engines; improved utilization of trucks in terms of loads; pricing, taxation, and import duties to encourage purchase of energy efficient vehicles; substitution of fuel such as alcohol, electrification, and LPG; and diversification of transport sector, e.g., railroads using coal and/or electricity and more efficiency in energy use per load.

efficient equipment would be 2-5 years. ([12]) Industrial projects with energy management programs are actively pursued in Brazil, Egypt, South Korea, and China.

With respect to electrical power systems, the World Bank has calculated that normal distribution and transmission losses account for 4-8 percent of total annual generation and 7-12 percent at peak hours. In half of the 76 countries reviewed, such losses were over 15 percent. Hence there is a potential for saving one half to one third of the losses normally incurred. Such reductions are important for it can be nearly 300 percent cheaper to reduce the loss of one kilowatt than to increase generation by an equal amount. Hence, reducing the total loss by 5-10 percent may save substantial amounts, for such a reduction should equal if not exceed the growth in demand.([13]) Losses in transmission and distribution of electricity have been estimated at 5 percent of total electricity output — a figure equivalent to one year's growth in demand.

These "losses" in energy, due to a variety of reasons, require two sets of responses: policies for reducing losses and policies for expanding supply possibilities. The following section looks at the supply side of the energy equation for developing and industrializing states.

4. The Supply Side

Worldwide production of commercial fuels in 1970-1980 increased by 3.6 percent per year and is expected to grow at 4.5 percent per year through 1995, despite the lower demand. During the 1970s developing states provided one fourth of total commercial energy supplies, with an anticipated increase to one third by 1995, thereby accounting for about 50 per cent of the total production increase.([14])

In 1980 the developing world accounted for 30 percent of global petroleum production, a figure that is anticipated to increase to 41 percent by 1995. Ninety percent of this production was concentrated in only eight countries. China and India alone accounted for 72 percent of coal production in the developing states. Overall, the developing countries are net oil and gas exporters and, by contrast, net coal importers.

([12]) World Bank (1983), p. 19.
([13]) World Bank (1983), pp. 22-23.
([14]) World Bank (1983), pp. 6-7.

At this writing, the crude oil reserves of developing countries (excluding OPEC members) are concentrated in nine countries. Five of these are estimated to have high oil reserves, i.e., 3000 million barrels or more: China, Egypt, India, Malaysia, Mexico. The remaining few — Angola, Brazil, Congo, and Tunisia — have more modest reserves, estimated at 1000-3000 million barrels.([15])

The natural gas situation is somewhat more encouraging in terms of potentials for a large number of developing states. Fourteen countries have high reserves (10,000 billion cubic feet or more), including several OPEC members. Nine countries appear to have 3000-10,000 billion cubic feet. See Table 4-1.

Gas development is less costly than had been believed earlier. And it is estimated that the expansion of natural gas infrastructure could lead to vastly greater gas utilization in developing countries. For example, current proven gas reserves, if developed, could cover almost half of these countries' commercial needs. As we note below, the development of gas infrastructure is critical if domestic price adjustments are to be made in the petroleum sector. Otherwise, the substitution possibilities cannot take place. Natural gas is used extensively in Algeria, Mexico, Pakistan, and Venezuela. Another five countries are on the verge of large scale utilization, namely Brazil, Egypt, India, Nigeria, and Thailand.

Coal, produced in thirty-five developing countries in varying quantities, is usually for domestic uses. As a fuel source it is 30-40 percent cheaper than oil in electrical power generation. Sixty percent of coal use in the developing world is concentrated in China and India. While coal reserves worldwide are enormous compared to oil (500 percent greater), there are several infrastructure and transport problems which constrain wider use. High initial investments, large gestation period for resource development, and high costs of transport place limitations on the benefits of this fuel source internationally. However, expansion of domestic uses for those countries with high imports can take place at relatively competitive prices. According to one estimate, the competitiveness of a coal mine is set at $100 a ton of delivered coal.([16])

On balance, increases in commercial energy production in new producers, that is, the conventional non-oil exporting countries, will exceed those of the less developed countries as a whole, with a growth rate of

([15]) World Bank (1983), p. 103.
([16]) Economist Intelligence Unit, Nr. 125 (1982), p. 34.

TABLE 4-1 - *Energy Reserves (Natural Gas).*

High *(10,000 billion cubic feet or more)*	Medium *(3000-10,000 billion cubic feet)*
Algeria	Bangladesh
Argentina	Bolivia
China	Cameroon
India	Colombia
Indonesia	Ecuador
Iran	Egypt
Iraq	Greece
Malaysia	Ivory Coast
Mexico	Tunisia
Nigeria	
Pakistan	
Thailand	
Trinidad and Tobago	
Venezuela	

Source: World Bank, *The Energy Transition in Developing Countries* (Washington, D.C.: World Bank, 1983), Appendix.

6.3 percent as opposed to 4.2 percent of all less developed countries. This means that a new group of industrializing countries joins the ranks of producers while remaining outside the frame of OPEC. In the following sections we highlight some of the implications of this new grouping.

4.1 *Exploring Activity*

Exploration for oil and gas in developing countries is generally undertaken through international (mainly World Bank) initiatives, through private ventures, or through a "mix" of both (as by the International Energy Development Corporation). Exploration has become a major policy priority for many of these countries. Although national governments themselves seldom make such investments, they are direct participants in the negotiation processes leading to concessions or contracts. A crowded development agenda almost by necessity precludes such allocations.

Fifty percent of all exploratory wells drilled from 1967 to 1976 were drilled in non-OPEC less developed countries. In other words, exploration was made in 71 out of 113 countries, and seismic and other exploratory activities were undertaken in an additional 22 developing states. However, 5416 out of 6501 of these wells were sunk in 16 countries, all of which had pre-1967 discoveries. Of the remaining 55 countries, encouraging findings were located in 25. But the drilling trend has declined, however, with 324 exploratory wells in 1977 compared to 602 in 1972 and a density of drilling of 7 per 1000 m^2 compared to a world average of 109 per 1000^2 in 1977.([17])

Virtually all increases in exploration activity have occurred in countries already producing petroleum. For example, 60 percent of these increases are in Argentina, Brazil, and India alone. By contrast, exploration activity in the non-oil producing developing states has fallen considerably since 1972. This is due to a variety of reasons, including poor incentive systems, political risks and, more importantly declining prices for world oil in the early 1980s.

Few detailed analyses exist for the impact of investments on exploration and development for a "typical" non oil-rich developing country. In most of these states investments are foreign, from multinational oil companies, and production sharing agreements govern the oil-share of the government and of the company when (and if) oil is found. Such longitudinal analysis is helpful as it "maps" out relative gains for all parties over time. We discuss one such example, in section 5.3 below, undertaken at MIT, which provides an illustration of utility for other developing states.

4.2 *Reserve Generation*

Argentina, Brazil, and India have 79 percent of all proven oil reserves located in non-oil exporting developing countries, excluding China.([18]) The proven oil reserves located in these states amount to only one percent of the world total, but this figure represents 14 percent of non-oil exporting countries' ultimately recoverable reserves. On a worldwide basis, their reserves account for 37 percent of the total. Most known reserves for the non-oil exporting countries are in Latin America (14-35 billion barrels), although Africa also has a considerable potential (13.7 billion barrels).

([17]) See Dundereley et al. (1980), p. 138.
([18]) Economist Intelligence Unit, Nr. (1982), p. 28.

Eighty-eight percent of all Latin America's potential is believed to be in three countries: Argentina, Brazil, and Colombia.

In Asia the ultimate recoverable reserves are about 14 billion barrels, with 1.9 billion proven, of which 85 percent are in India alone. In Africa the onshore and offshore ultimately recoverable reserves are primarily oil, with some gas. Of the 20-38.5 billion barrels total, 75 percent is located in 30 countries, with Ghana, Somalia, Ethiopia, Sudan, Mauritania, Chad, Senegal, Mozambique, Mali, Kenya, and Madagascar having the most promising prospects.

Despite Africa's potential, only 148 wells were drilled from 1975 to 1978 and only 13 rigs were operational, eleven of which were located in the Ivory Coast, Niger, and Sudan. This number represents only seven percent of those rigs operating in Latin America. In Asia 100 rigs were operational, a figure which includes 44 in India.([19])

While exploration activity and reserves generation have not proceeded at the rate that has been expected, the scope for expansion is great. Yet several factors obscure this potential: declining world oil prices, prevailing risks in developing countries, insufficient incentives for foreign enterprises, and inability to expand national investments due to resource constraints, technical and skill shortages, political considerations, and competing priorities.

4.3 *Supply Management*

The interaction of energy and macroeconomic policy makes the organization of oil, gas, and coal industries difficult yet essential. The difficulties are due to the necessity of involving numerous agencies both public and private. The essentiality is created by the fact that macroeconomic goals are dependent upon energy policy, and success in the latter depends upon efficient macroeconomic policies.

In the past multinational oil companies dominated entire operations in fossil fuel development and management. In particular, the petroleum and natural gas sectors in developing countries have historically been established hy international oil companies making essential calculations based on their assessment of profitability for their worldwide operations. With changes in the oil market, nationalization of the oil industry, and

([19]) Economist Intelligence Unit, Nr. (1982), p. 48.

government takeover of most operations, the management of the energy sector has adjusted accordingly.

The diversification of the supply of crude petroleum internationally coincided with the national governments' establishment of domestic price controls. This resulted in involvement of the various government agencies, invariably leading to centralized decision power in one agency. The underlying logic is to increase efficiency and rationalize regulation of proliferation of multiple demands on energy resources.

The near universal establishment of national oil companies to coordinate production and marketing contributed to the vertical integration of this sector. National oil companies are expected to control all facets of the sector and as such will be the locus of managerial and technical expertise. Their role is especially critical in the interface between national government and international oil companies. They are, however, almost universally understaffed, inexperienced, undercapitalized (due to price controls and subsidization) and lack of access to necessary technology. ([20]) The Latin American experience, examined in detail recently at MIT, illustrates both the potentials and the difficulties facing public sector energy enterprises in developing countries. ([21])

Because the technology, capital cost, and expertise involved in refining and marketing stages are less extensive than on the production side, the development of national downstream activities by national governments has been more pronounced (see Table 4-2). In some developing countries downstream operations are on a world scale. However, for most of these countries such operations have tended to be small and inefficient. Substantial improvements are needed to update facilities, reduce bottlenecks, and overhaul their operations. Yet there is scarcity both of capital and of technology. Substantial investments are required as most refineries were built to meet the requirements of the international operators and not those of the national governments in the country of operation. By contrast, controlling the marketing of a products industry is the least technologically demanding component of the oil-system. On balance, national companies have been rather effective in controlling distribution.

([20]) Economist Intelligence Unit, Nr. (1982), p. 30-34.
([21]) Choucri (1982), pp. 142-143.

TABLE 4-2 - *Variation in Local Petroleum Refining Capability in Oil-Importing Developing Countries.*

High *80,000 b/d or more*	Medium *20,000-80,000 b/d*	Low *Less than 20,000 b/d*
Argentina	Dominican Republic	Afghanistan
Brazil	Ghana	Bangladesh
Chile	Ivory Coast	Burundi
Colombia	Jamaica	Costa Rica
India	Kenya	Cyprus
South Korea	Morocco	Dominican Republic
Pakistan	Paraguay	El Salvador
Philippines	Senegal	Ethiopia
Singapore	Sri Lanka	Gambia
Taiwan	Thailand	Guatemala
Turkey	Tunisia	Guinea
	Uruguay	Guinea-Bissau
	Zaire	Guyana
	Zimbabwe	Honduras
		Lesotho
		Liberia
		Madagascar
		Malawi
		Mali
		Mauritania
		Mozambique
		Namibia
		Nicaragua
		Niger
		Panama
		Rwanda
		Sudan
		Tanzania
		Timor
		Togo
		Uganda
		North Yemen
		Zambia

Source: Economist Intelligence Unit, *Petroleum Investment in Developing Countries*, Report NR. 132 (London: Economist Intelligence Unit, 1982), p. 25.

5. Pricing Issues

Despite the highly regulated environment in many developing countries, prices continue to exert a strong influence on economic performance and on investment decisions. The world energy prices determine propensities to invest in exploration and in development (thereby potentially expanding sources of supply). Prices prevailing domestically, generally set in place by overarching social policies and priorities, condition internal consumption patterns and sectoral distribution. The disjuncture between domestic and international energy prices itself poses serious problems for rationalizing planning in this sector.

Domestic pricing of petroleum products and natural gas continues to be a critical issue in all developing countries. While some have increased petroleum and primary energy prices to reflect real scarcities, there remains considerable scope for change. Oil-exporting countries in particular are vulnerable to the distorting effects of unrealistic prices. Rapid growth in domestic consumption, pushed by low prices, cut into exports. This problem is particularly acute for Egypt, Indonesia, and Nigeria, among others.

Some adjustments have been made in non-oil exporting developing countries by passing energy price rises directly on to the consumer. The real domestic price increase of petroleum products in local currency between 1975 and 1981 was 40 percent in Korea, 60 percent in Brazil, Pakistan, Philippines, and Turkey; and over 200 percent in Yugoslavia and Colombia. Pakistan and Brazil illustrate well the impacts of price changes on energy consumption. Pakistan raised its diesel oil prices (which for a sample of non-oil exporting developing countries rose from 38 to 61 percent of gasoline prices from 1975 to 1979) and consumption dropped from 550 to 300 percent of its gasoline consumption in five years. Brazil decreased the price of diesel and correspondingly the consumption rose from 90-150 percent of gasoline use over the same period.[22]

The picture is more stark in the electricity sector of the non-oil exporting developing countries. Of the 33 countries surveyed by the World Bank, 18 increased tariffs in real terms since 1974, but only seven had prices equalling the marginal cost in the long term. An increasing number of countries have committed themselves to raising tariffs, including Bangladesh, Indonesia, Kenya, Nigeria, and Sri Lanka. Of course, prices do

(22) World Bank (1983), pp. 16-17.

not operate in a vacuum, there are inevitable social adjustments to any effective pricing strategy.

5.1 *Prices and Demand Management*

One important policy instrument for containing demand growth, pressing for conservation and substitution, is raising domestic energy prices. In many developing states prices of fuels are maintained well below international standards, due to the social equity policies of the 1950s and the 1960s. While there is considerable scope for domestic price increases, it is generally feared that the social, political, and even economic costs of raising prices would be extensive. Many countries are hesitant to make this commitment.

For purposes of analysis, however, two issues need to be resolved: (1) determining precisely how energy is used in the economy in different sectors and in which forms; (2) determining the economy-wide effects as well as the sectoral effect of raising domestic energy prices as a key component of demand management strategies. Several constraints exist for making the necessary analysis. There are not enough data about sectoral use of energy, nor the analytical basis upon which to draw conclusions regarding price policies for demand management. Nonetheless, drawing upon detailed analysis for one developing country undertaken at MIT in collaboration with its governmental and energy organizations, we can draw some important conclusions. This is the case of Egypt, an industrializing society with a large petroleum export sector and dramatically expanding domestic consumption.

This analysis was undertaken in two stages: first, determining the precise energy uses in the economy (through the interindustry input-output table, which we expanded into a social accounting matrix to include the economy-wide flows); and second, constructing a 10-sector model of the economy to show the short-run, immediate effects of price policies.(23) Our conclusions are presented here in this parallel fashion as well:

With respect to energy uses, we found that there have been substantial changes in patterns of energy use, and the role of energy sectorally in the two years we examined in detail, 1977 and 1979. In the space

(23) Nazli Choucri and Supriya Lahiri, "Short-Run Energy-Economy Interactions in Egypt", *World Development*.

of two years, the internal shifts in energy flows were extensive. For example, in only two years, exports of crude petroleum expanded from 8.1 percent of all exports to 46.2 percent. Exports of refined products doubled: from 3.5 percent of all exports in 1977 to 7.7 percent in 1979. In 1981/82 exports contributed 2.76 billion to the country's balance of payments. The sector as a whole, between 1977 and 1979, made the following contribution to final demand, value added, and gross production.

The energy sector increased in importance in the economy from 1977 to 1979. For example, energy's share of final demand rose from 2.2 percent to 17.6 percent. Energy's contribution to gross production rose from 5.2 percent to 12.5 percent. The share of gross value added supplied by the energy sector rose from 5.3 percent to 17.5 percent. And, finally, inputs to the productivity of the energy sector increased from 4.5 percent of all industrial inputs to 7.2 percent.

Thus, we conclude that for Egypt, as perhaps for many other developing countries, economic growth and structural changes have had major impacts on energy uses domestically. It is therefore important to obtain better information about internal energy use. At this point we believe that, in the Egyptian case, for example, there have been even more changes from 1979 to 1984.

With respect to the impacts of demand strategies based on domestic pricing changes, we explored those impacts through a structural general equilibrium model of the economy that incorporates the essential features of this particular economy.([24]) Current domestic price of petroleum in Egypt is about 20 percent of the internal market price equivalent. Almost 50 percent of energy used is petroleum based. Different sectors will respond differently to changes in energy prices, *and* price determination mechanisms differ from sector to sector. Thus, these new considerations provide the core of the problem. We wanted to know how the economy as a whole will adjust to higher prices, and how different sectors will respond.

The model draws upon the well-known linear expenditure system of demand equations to arrive at the sectoral consumption level. This set of equations, derived for utility functions, is the basis for calculating demand, or the consumption levels related to price and income variables for each sector. Given the different behavioral assumptions and the

([24]) Ibid.

different identities built around a social accounting matrix, the solution is determined through several adjustment mechanisms. In this model, these mechanisms are the Keynesian output response in the quantity-clearing sectors, the "forced saving" mechanism via the rise in the prices of output relative to wage, adjustments in the trade deficit, and the surplus available in the government current account.

The conclusions are as follows: We found that the responses of the increase in the sectoral price levels will vary over the different sectors.

The changes in relative prices will lead to a rise in the level of profit income from the petroleum sector. A large proportion of this profit income will be going into the hands of the Egyptian government because of the large share of the government in the petroleum sector and in the other sectors of the economy. This increased government income will result in higher government savings leading to leakages in purchasing power.

One related effect is that real wages will fall. This will occur because of the short-run nature of predetermined nominal wages. Thus income will be redistributed away from wage and wage earners to profit recipients. A large amount of the increased profit will accrue to the government owing to the large share of the government in the public sector undertaking. (Of course, government can choose in turn to distribute profits back to wage-earners if it so chooses, but we do not examine this policy).

An *increase* in the domestic price of oil will lead to a *reduction* in the level of economic activity of the different sectors of the economy. Real value added will fall by approximately 2 percent and household consumption of petroleum products will decline by about 13 percent. Overall, the rise in domestic petroleum prices will create difficult adjustment problems in the short-run involving *increased inflation* (due to cost-push inflationary pressures originating in the petroleum sector) and *contraction of output* (brought about by a fall in aggregate demand). This will lead to the underutilization of capacity.

We undertook further analysis to identify the prospects for substitution from petroleum uses to natural gas. It became clear that in those sectors where natural gas can be used, substitution possibilities are inhibited if bottlenecks in the gas system are not removed. If the domestic supply of natural gas remains fixed, then the contractionary effects on the economy indeed have become more severe.

The above leads to one conclusion relevant for *all* demand management alone strategies for *all* developing countries: that energy demand management alone cannot bring about desirable impacts on the economy unless efforts are made to prevent cost increases which occur in other sectors of the economy.

The macroeconomic implications of domestic petroleum pricing strategies in Egypt are extremely important and should be considered carefully. Simply suggesting lifting of domestic subsidies, increasing domestic energy prices to world prices, will not have the intendend effects unless other measures are adopted as well. Treating the energy sector in isolation from the rest of the economy will be counterproductive and lead to adoption of measures that may even have detrimental effects. An overall energy/economy strategy is required in which adjusting domestic prices toward international prices is only one element.

5.2 *Prices and Expanding Supply*

The price of oil has two distinct impacts on producer countries: for the established producers it serves as a signal to moderate production and implement cutbacks as a means of sustaining prices. For new entrants in the market, price serves as a signal to allocate investment in exploration and development. Investment decisions, so critical for new producers, are closely tied to prevailing prices.

Developing countries with potentials for expanding energy generally rely on external sources of investments in exploration and development. This class of countries is different from the traditional OPEC producers as their reserve potentials are much more limited, and the financial basis more modest. Thus governments cannot easily divert resources for energy investments. As a result, adopting appropriate measures for attracting foreign investment is of major importance. In the petroleum sector production sharing agreements between government foreign companies are emerging as the norm for the 1980s.

In recognition of the reality, we have developed at MIT a simulation model to examine the impacts on production of investments in exploration and development — given basic geological information about the country in question. One essential intent of this model is to determine (1) the impacts of world prices and domestic prices on production and exports; (2) the distribution of oil produced — as between government and international oil companies — and then the allocation of government share to domestic consumption vs. exports; and (3) impacts of energy investments on production capacity and additions to capacity.([25])

The Energy Development Model (EDM) is devised as an analytical tool to assist government agencies and investor companies to pull together relevant information from various fields — combined in a conceptual framework to produce simulations of future developments. The model integrates basic information useful for analyzing production possibilities and actual production for new oil exporting countries — the non-OPEC potentially important producers. For illustrative purposes, Figures 5-1 and 5-2 show two sets of results from a base case analysis for one such country, Egypt. This choice is made here to maintain consistency with the discussion of demand adjustments in section 4 above. The EDM model and simulation style is designed for this class of country, namely countries with strong export potential and relatively strong domestic consumption.

Figure 5-1 shows prospects for Egyptian oil production under two scenarios: one assumes that current reserves are more modest than estimated, as noted in official sources, and the other assumes that reserves are higher than those presently recorded. The base scenario rejects currently known reserves. The actual production of Egypt is also placed on the Figure for comparative purposes and tracks the base case as well.

Figure 5-2 shows the distribution of production under the existing production sharing agreement for the base case. It shows total Egyptian oil production under current conditions (and parameters) and how this production is allocated given existing contracts, and assuming no changes in the clauses over time. Thus we show the volume of cost recovery oil over time, the production-sharing oil, the foreign oil company share of production, and Egyptian share of production. This base case, allocating produced oil to the parties in question, will of course change significantly if we assure changes in the contract clauses. The characteristics of the base case are existing world prices, currently known reserves, and existing contracts with foreign oil companies.

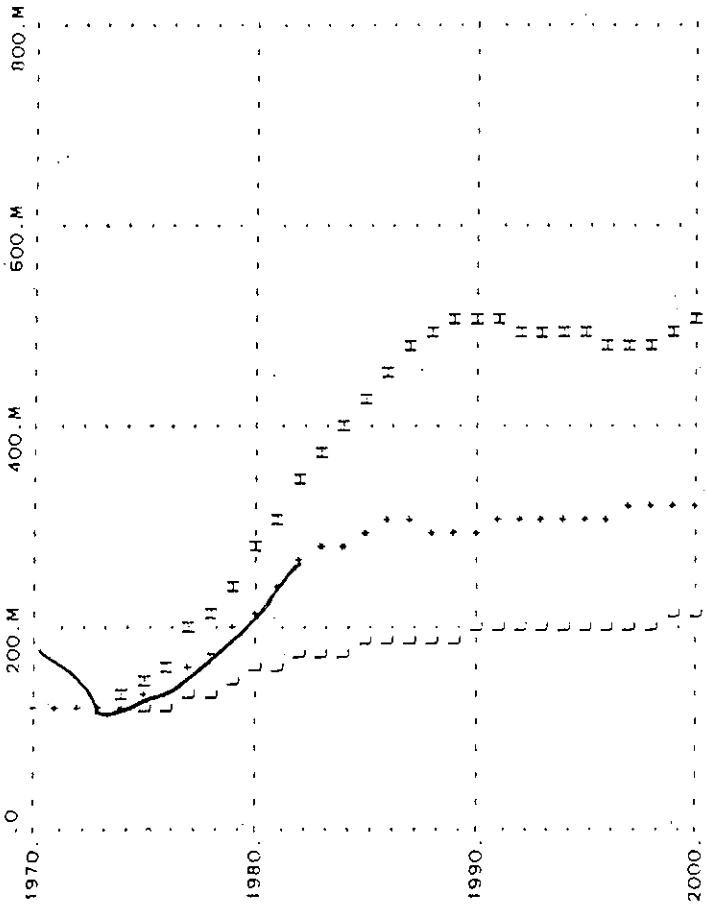
The purpose of these illustrations is to indicate the "unfolding" of

([25]) See Energy Development Model (EDM), structured with Michael C. Lynch, based on the International Petroleum Exchange Model (IPE) as presented in Nazli Choucri (with David Scott Ross) *International Energy Futures: Petroleum Prices, Power, and Payments* Cambridge, Mass.: The MIT Press, 1981).

Energy Development Model

The Egypt Case: Oil Production

(million barrels per year)

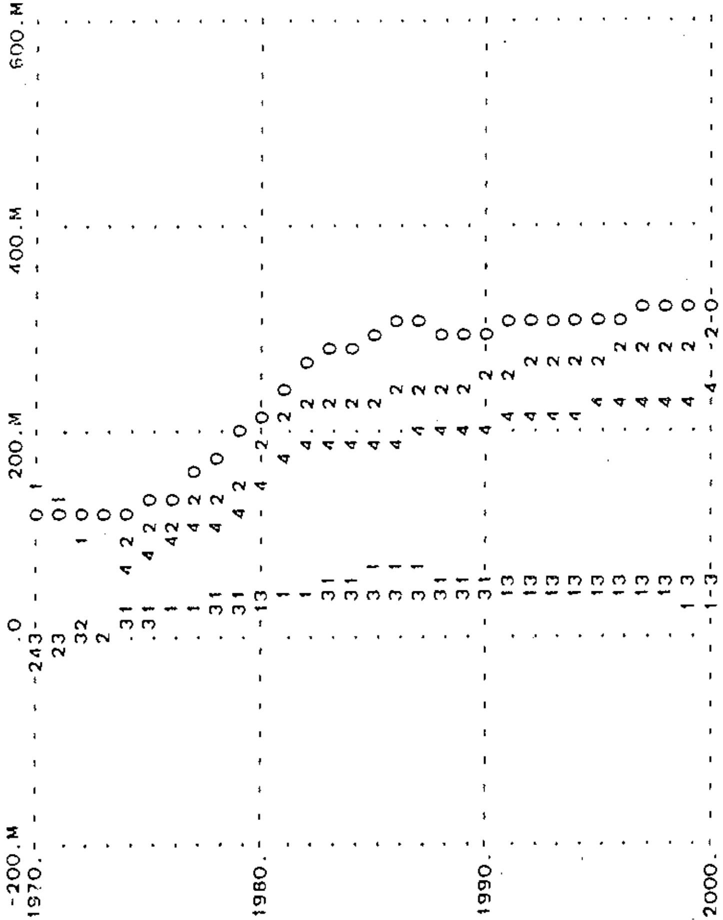


— = Actual Production
* = Base Scenario
H = High Resource Base
L = Low Resource Base

Fig. 5-1

Source: Nazli Choucri and Michael C. Lynch, *Energy Development Model: The Case of Egypt* (MIT Technology Adaptation Program, in press).

Energy Development Model
The Egypt Case: Production Distribution
(million barrels per year)



0 = Total Production
1 = Cost Recovery Oil
2 = Production-Sharing Oil
3 = Oil Company Share of Production
4 = Egyptian Share of Petroleum

FIG. 5-2

Source: Nazli Choucri and Michael C. Lynch, *Energy Development Model: The Case of Egypt* (MIT Technology Adaptation Program, in press).

the oil sector and its performance for one of the new important oil producers. It would be extremely revealing to parameterize the Energy Development Model (EDM) to other countries, particularly their petroleum and natural gas potentials.(26) Such an exercise would be very useful as a tool for policy, and for government policy assessment.

6. The Social-Political Dimension: Problems of Adjustments to Changing Energy Environments.

The changing energy environment has created new social strains in most developing countries. Social costs are mounting for everyone. For the oil-rich countries, the major oil-exporting countries, the combination of new wealth and new constraints creates new social tensions, and the revenue cuts due to lower oil exports and prices may create even greater pressures. For oil-importing countries, the oil-poor states, social strains have resulted from policy attempts to adjust to new scarcities. For everyone, there is evidence of strain and efforts to adjust to the changing energy environment. On balance, at least three types of social and political adjustments are becoming apparent and must be dealt with:

1. Adjustments to government attempts to respond to new constraints through new policies, regulations, and so forth;

2. Adjustments to new investment patterns and allocation for growth, such as those due to oil investments, or infrastructure projects related to availability of finance;

3. Adjustments changing conditions created by a changing international energy environment.

The convergence of these factors contributed to political pressures for many developing countries. The experience of countries with direct policy intervention in the energy sector is still fairly new. Nonetheless, domestic energy-related policies on both the supply and the demand sides are becoming intensely political. For example, when Brazil announced a set of policy measures in 1977 to curb demand and save about $120

(26) See Nazli Choucri and M. Zaki Shafei, *Energy Policy Project in Egypt: An Overview*, TAP Report 83-20 (MIT Technology Adaptation Program, 1983).

million in the oil import bill,([27]) such policy interventions were not without their immediate social costs. Strikes and riots broke out in Brazil, Peru, and Santo Domingo specifically over increases in petroleum prices and shortages of supplies. In Ecuador, another example, the government has devised a variable petrol-pricing structure in the effort to ward off riots. In short, direct interventions in the petroleum sector created considerable unease.

On the supply side, there is yet another source of social strain, evidenced, for example, by the case of Mexico. In 1981 the government tried to abandon plans to limit oil production in order to help curb inflation. Some officials regarded any proposal to expand oil production to the limit as inflation-producing and likely to create further destabilization. Hence efforts to curb production were made (this before the advent of today's glut in the oil market). The complex economic process of reconciling a set of seemingly irreconcilable objectives — maximizing economic growth, reducing unemployment, curbing inflation, and so forth, — was all built around predicted levels of export earnings. However, irreconcilable objectives cannot be reconciled overnight, and social strains can become aggravated further.

Then, too, the perennial problem of unemployment which plagues most developing countries emerges at the forefront once again in oil-rich and oil-poor countries. The requirements of rapid industrialization tied to a strong energy sector almost invariably impose strong preferences for capital-intenisve investments. Untangling the causes of social strain is almost impossible to do, given the scanty information available. Despite protests and social unrest, there is some evidence of positive adjustment to energy policies, as noted earlier. Yet, the situation in many countries is still transitional: there is a search for appropriate policies for both the supply and the demand sides.

In the Gulf region of the Middle East and the exporting countries of Latin America, patterns of investment appear to be distorting the process of economic growth and aggravating structural dislocations. Agricultural production specifically was low, partly out of neglect. Oil wealth is being used in larger shares of the national budget. The sudden in-

([27]) See *IMF Survey*, February 1977, and Cloraldino Soares Severino, "The Energy Problem and Transport: The Brazilian Experience", December 1980. Prepared for the Seminario, "Impacto del Costo de la Energía en el Sector Transporte", 1-3 December 1980, Bogota, Colombia. Translation available at the Department of Political Science, Massachusetts Institute of Technology, Cambridge, Mass.

creases in the oil revenue in oil exploring states had unleashed a new pattern of domestic investments.

In some developing countries the social and economic impact of oil exploration and development has contributed to the disruption of agricultural development plans through erratic and unplanned economic changes. The "pull" of labor has accentuated "squatter settlements" and contributed further to migrant flows from rural areas. At the same time large public sector energy enterprises suffer from labor shortages of both skilled and semiskilled labor.

Some countries, like Venezuela, have considered establishing financial mechanisms for regulating investments and oil income. The government had declared it would place half of its total oil income in the Venezuelan Investment Fund as a means to reduce inflationary pressures and control the developmental process. The fund is designed to finance a new petrochemical industry and infrastructural projects such as shipbuilding, a massive steel complex, and a long-range agricultural program designed to help Venezuela attain self-sufficiency.([28])

Changes in oil prices and massive oil income in the 1970s resulted in transformations in internal power relations in almost all oil exporting countries. Four trends stand out: the rapid expansion of the bureaucracy and government agencies, the growing importance of technological investments as one of the strongest and most coherent trends, the importance of the banks, and, last, the clear growth and predominance of public enterprises related to petroleum and energy.

Among observers of developing countries, it is said that the oil-rich states in the 1970s developed a "petroleum syndrome". The relationship between growth, equity, and social change has been seriously disturbed, and the traditional patterns of social and political relations changed significantly. The emerging importance of technocrats and entrepreneurs in the political system changed more traditional patterns of power and wealth. The basis of the new power had become the country's depletable resources, and not expansion of its productive capacity. Hence the impacts of energy investment patterns transcend conventional economic concerns, and bear directly upon a country's political arrangements, and the evolution of its social structure.

The distribution of benefits tied to key economic decisions is render-

([28]) George W. Grayson, *The Politics of Mexican Oil* (Pittsburgh: The University of Pittsburgh Press, 1981), p. 118.

ing energy related decisions synonymous with decisions bearing on the viability of the society itself. In several potential energy exporters, the public sector is held accountable for lack of success. For example, in Brazil the apparent lack of success of Petrobras to make any significant strikes borders sometimes on becoming a political issue. "Why wouldn't God have conceded this present to us?" lamented the company's first president. ([29]) Large sectors of the country's public have occasionally expressed anger at Petrobras' apparent inactivity domestically, especially in view of its success in Iraq. "If we can discover oil abroad, why can't we do so in our own country?". ([30])

These reactions are all symptomatic of increasing expectations far in excess of actual performance. States everywhere are becoming cognizant of the pressures created by a changing energy environment. The nature of the pressures differs, as do the political responses. In the international arena, there is evidence of collaboration. Although observers of development tend to stress the dislocating effects of the energy environment, caution and a modicum of optimism may well be in order. Indeed, the most favorable adjustments have occurred in the ability of most countries to weather the pressures of the 1970s. The challenge now is to adjust to the demands of the 1980s and the changing international energy environment.

([29]) *New York Times*, September 21, 1979, pp. D1, D12.
([30]) Ibid.

DISCUSSION

MALU

Dr. Desprairies, concluding your speech, you listed a certain number of things which have to be done, and one of these was to respect the contracts which have been signed. But what would you do when somebody, say 20 years ago, signed a contract which gives 90% of the profits to the exploiting company?

I have a question for Dr. Choucri. You discussed the importance of the energy management problem, underlining that it is not only a technology-related exercise, but that it is also related to political and social factors. I fully agree with this general statement. The integration and aggregation, both in space and in time, of processing industries and of energy-intensive activities is one of the basic principles of energy management. But how can this principle square with the disaggregation trend that is progressively emerging in society? How can we have, at the same time, aggregation to optimize processes without interrupting the decentralization dynamic taking place in societies?

SUAREZ

I have some remarks on the point that Dr. Choucri made on the relationship between international oil prices, giving the indication for production, and the domestic prices giving the indication for consumption. In some developing countries the domestic oil price is also an index for production because internal production is developed in relationship not with international prices but with domestic ones. I just wonder why international prices should be more rational than domestic ones.

There are cases which clearly show the kind of negative consequences which can occur in developing indigenous oil fields quickly. One could ask what is a good strategy to develop oil reserves respecting the normal evolution of the economy, if there is one.

DI VECCHIA

Dr. Choucri, we are talking here about oil prices, and how they relate to inflation. It seems to me that we should also take into account the devaluation of local currency in terms of the dollar and also the value of local products compared to oil. This could help us to figure out which parts of society would have to pay for the oil imports in order to increase exports.

SMITH

The seventies can be seen as the time in which producing countries gained control over the upstream operation in the petroleum market: exploration, production and the pricing of crude oil. The 80's in the oil market will be a time in which many producing countries are going to gain control over the downstream operation: refining products, marketing, transportation. This has a very interesting implication for developing countries in addition to those mentioned this morning. In particular developing countries tend to have quite a skewed demand for refined products. Oil of course does one no good unless one gets the kind of product one needs. One does not burn crude oil, one burns gasoline, kerosene or residual fuel oil. Developing countries need access to flexible refineries; otherwise they may find themselves in the bad position of decreasing their overall oil use, but actually increasing their need for crude oil, depending on the extra products they need. All this requires governments not only to consider their need for oil but also to carefully consider the demand for each of the major types of oil and to see how the refining picture fits it. They can easily get themselves into serious trouble increasing oil imports and having an excess of one product or another to try to dump on a world market which is flooded with such products.

LANDSBERG

Mr. Desprairies, I wonder whether you could say a little more about the expected size distribution of the unrecovered oil resources.

I would also like to know Miss Choucri's opinion on the question of underpricing oil products compared to the world prices. It is an important question because underpricing encourages consumption, it misallocates investments in terms of energy using capital. If prices remain understated, this probably leads to a lack of diversification, and probably also to a less than optimal allocation for research. I am not sure that underpricing would be a good solution.

LEMKECHER

La conférence de Monsieur Desprairies a été centrée sur les possibles solutions aux problèmes de l'exploration. Pour un bon nombre des pays en développement, il ne s'agit pas seulement d'un problème de recherche et d'exploration, mais aussi, et malheureusement, de développement d'un certain nombre de petits gisements. Je voudrais savoir quelles sont les possibilités de développement de ces petits gisements des PVD.

ZEGHBIB

Mr. Desprairies, I have a comment on the exploration strategies of the international oil companies. Basically two criteria are followed: the near economic one and what is called the risk evaluation one. In the risk evaluation criterion, of course, there is the political risk component, and I wonder if you can develop this point.

Speaking about respecting the contracts, I surely agree that when one signs a contract, one ought to be sure that the contract is going to be implemented; but both sides have to respect it, governments and oil companies, and that is not always the case; see, for example, what happened with the exploitation of natural gas.

I also have a question to Dr. Choucri. You presented the case of Egypt highlighting the point that some bottlenecks have to be removed in order to substitute oil with natural gas. Since we are having the same kind of problem in Algeria, I would appreciate it if you develop this point.

DESPRAIRIES

Mr. Malu, in answer to your question about unfair contracts, I think that in all contracts there is a so-called equity clause that provides that both parties have the right to ask the other to revise the contract if the economic situation has changed to such an extent that the contract becomes really very different from the one which was stipulated originally. I think this is the case you mentioned, and this is the case for the application of such a clause. What I meant in my comments was an abusive application of this clause, when it could appear favourable for one party to get out of an embarrassing contract. I think that in these circumstances a contract has to be revised when it becomes inequitable.

Mr. Smith, you observed that the problem exists not only for crude oil but also for oil products, and you mentioned the problem of adjustment between crude oil and the market because of the excess demand for medium distillates in both the developed and developing countries. It is a problem that companies, more than governments, have to tackle. Companies are building so-called conversion units to extract much more medium distillates and light products from fuel oil, and up to now the balance has been attained.

Dr. Landsberg, roughly speaking, I would say that in the sixties the average size of new fields in terms of capacity was in the figure of a billion of barrels. Nowadays a field of 150 million barrels — the North Sea fields for example — is considered a good one. It is worth saying that the only consideration which affects the exploitability of oil fields is not the size but the cost.

Mr. Lemkecher, you asked me what can be done with the so-called marginal fields. I would suggest that the first remedy is a very favourable taxation system, otherwise the company will not make the investments to develop the marginal fields. The decision to exploit is in the margin between the expected costs and the expected value of the market, but I think marginal fields under the present price conditions should be exploited, if the price does not collapse.

Mr. Zeghbib, you asked the question about risk evaluation parallel to economic evaluation. What I see is that in risk evaluation, the component sometimes called political risk has a much lower share in the decision of the company than it had some years ago. Experience shows that in many circumstances governments made changes and the contracts remained in force because it was in the joint interest of both parties.

CHOUCRI

Maybe it is not good form to remind you that we do live in a very unjust and unequal world and prevailing price structures reflect prevailing power structures, whether international or domestic. By training I am a political analyst, so I see conflict and power underneath every rug, but I also remind you that the events of 1973 were intensely political events. There are those who argue that the market conditions that made it possible have changed internationally, but in my opinion we are now acting and responding 10-12 years later to the consequences of profoundly political events.

By the same token, the domestic price structure in any society is also a manifestation of the power structure. Let me specify. The prices set in many developing countries, Egypt is only one case in point, in the early 50's and 60's as part of the decolonization and independence process of these countries, were set to subsidize society as a whole and to assure that society would support government. Now governments have to change this policy and go back to market prices. They need all the oil they can sell in order to increase their import of foreign exchange for the country. If exports are diverted to meet domestic consumption the governments' own balance of payments will be adversely affected. Let me now turn to the issue of contracts. I must tell you that as a political scientist I also see contracts as a manifestation of the relative power of those who have signed them. If you go back to Mr. Malu's statement, unequal contracts simply reflect the distribution of power. One of the reasons why I, as an academician, spent time and effort modeling the consequences of contracts is to understand the evolution of power distribution as contracts are implemented, and I do believe that those who have signed on the dotted line on the 90-10 contract, either did not understand fully what they were doing or they did not have very many options.

Let me move quickly to the notion of the political factor in risk evaluation. I am inclined to agree with the statement which was made, but perhaps political factors do not enter as much in the decision to invest as other factors.

On Dr. Landsberg's statement about the solution, I would say that solutions depend on humans, and since not all economies are structured in the same fashion, I am not going to state what the solution might be since the structure of the economies differs so substantially and the market clearing mechanisms do differ in different economies.

Fundamentally what we are talking about is a lack of understanding on our part about the nature of trade-offs. The long-term, the short term, the political, the economics. On the observation about natural gas I would say that the Egyptian case is not really a good one for prescription or even for comparison, because Egypt has only just begun to appreciate the natural gas potential, and to seriously consider the possibility that it might do something to identify bottlenecks and reduce them. Several preliminary measures have now been taken: separation between the oil and the natural gas management systems; the search for an appropriate pricing structure; definition of the housebold distribution network.

COAL IN DEVELOPING COUNTRIES: PROSPECTS AND PROBLEMS

OLIVIERO BERNARDINI
Centro Studi Energia "Renzo Tasselli"
(CESEN) Genoa, Italy

1. *A new era of coal*

The return to coal witnessed during the 1970s was as sudden and, perhaps, as unexpected as its demise in the post-War period. In the 1950s, with development of the newly discovered supergiants of the Arabian peninsula and world-wide extension of scale economies in transport of crude, refining and distribution, the price of oil products became so low as to initiate a process of ousting coal from practically all markets which lasted the better part of two decades. Coal continued to be used in dedicated uses such as metallurgy but except for this sector, which developed a robust and growing international market, coal use became increasingly restricted to limited areas of coal bearing regions where exceptionally low coal extraction costs and preexisting fully amortised transportation systems based on rail provided an effective bastion to continually decreasing oil prices.

Only in a few cases, such as South Africa, did particularly convenient coal deposits combine with national security reasons to determine coal utilisation in sectors such as liquid fuels conversion where coal was no longer economical in normal market terms. Efforts to subsidize coal use in many European countries, aimed at smoothing over the traumatic effects on the mining industry, were essentially unsuccessful in inverting the new trend established with the remarkably convenient fuels based on oil. No manner of warnings on the relatively limited oil resource base, already echoing in a number of circles and which at that time gave oil resources an expected lifetime of about 20 years [1] were effective in slowing down the demise of the coal era though they did play a significant role in opening up the emerging nuclear age.

The basically economic nature of the rationale underlying the relative fortunes of oil and coal became clearly evident in the remarkable ease with which the change in relative prices between oil and coal occurring during the 1970s, determined a rapid and unforgiving inversion in previously acquired trends. Even before the governments of most consuming and producing countries had the chance to take effective policy measures to favour the come-back of coal, for security as much as for economic reasons, coal had practically everywhere acquired a new vigour of its own requiring neither prodding nor subsidies. The apparently effortless reentry into the market was determined by an increasing divergence between steam coal and fuel oil prices which continued to persist even after oil prices had begun to decline somewhat in 1981 (figure 1).

The turning point in the short-lived oil era was 1977, just three years after the first oil price shock, a delay barely long enough for utilities and industrial users everywhere to recover from the abrupt change in economic relations, take stock of the new situation and formulate suitable expansion policies. The first result of the decline in relative coal prices was that old coal fired plants due for retirement were maintained functioning for a few more years. Where dual use was permitted or possible with minor modifications, plants which previously had been using fuel oil were unceremoniously turned back to coal. Longer lead times in the order of 3 to 5 years were required to build new plants based on coal. All three of these effects were variously present, in different degrees according to country, in the events that followed in the short but, nonetheless, indicative period of 5 to 6 years, for which statistics are presently available.

The true situation is somewhat masked by the slow economic growth occurring throughout most countries during the whole decade beginning with 1973, which was particularly unrelenting on the steel industry and other sectors which are potential users of coal. The annual rate of growth in coal production and consumption in the world as a whole in fact declined slightly from 2.56% in the period 1973-77 to 2.22% in the period 1977-82. This decline was, however, nothing compared to the absolute negative growth witnessed by oil use which declined at the rate of 3.4% a year after reaching a peak consumption of 3125 Mt in 1979.

To give an idea of the magnitude of the come-back made by coal, we note that while in the period 1973-77 the ratio of coal growth to total energy growth in the world as a whole was 0.90, in the period 1977-82, this ratio had jumped to a remarkable value of 2.13. In this period oil lost 49% of the total world market increase in energy requirements. While hydro and nuclear captured respectively 21 and 25% of the market and natural gas 42%, coal turned out to be by far the main

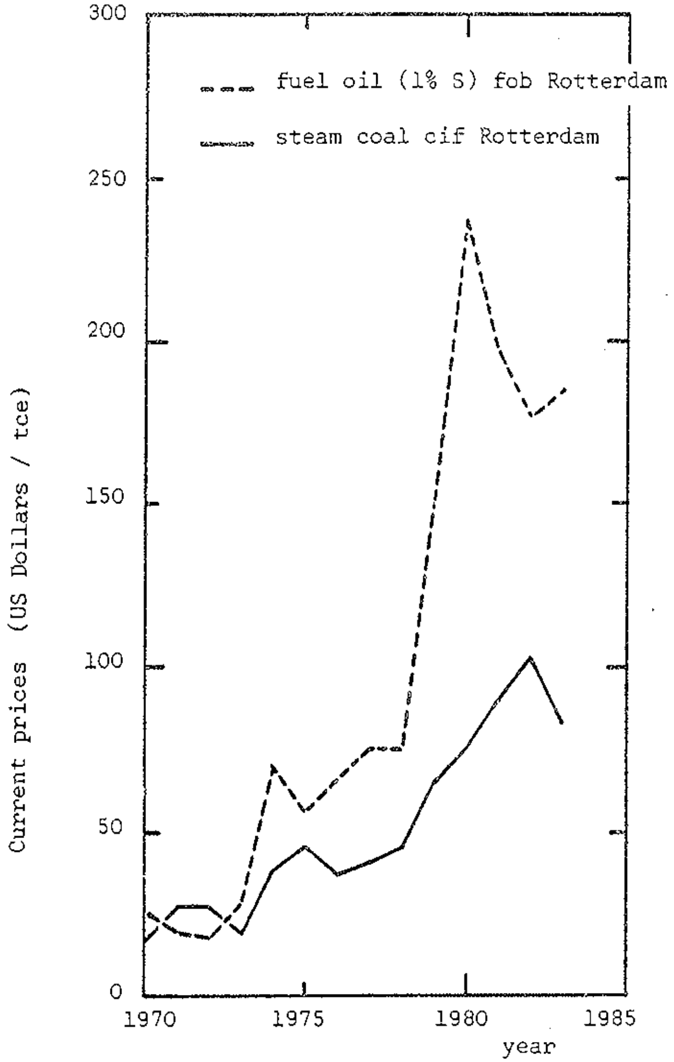


FIG. 1. Oil and coal prices 1970-83.

TABLE 1 — *Contribution of primary energy sources in increasing energy supplies 1977-82 (%).*

	1960-77	1977-82	WOCOL 1977-2000 case A	case A1	case A2
oil	67	−48.8	10	−10	−10
coal	2	61.4	37	55	67
natural gas	21	42.4	8	10	10
hydro	5	20.5	13	13	13
nuclear	5	24.6	32	32	20
total	100	100.0	100	100	100

resource in expanding energy markets, contributing some 61% to the total increase in consumption between 1977 and 1982 (table 1).

These results have in many cases surpassed even the most optimistic expectations of many policy makers in government and industry, whose lack of faith in the new era of coal was no doubt rooted in the spectacular demise suffered by this fuel during the previous quarter of a century. With few notable exceptions the timid forecasts of coal growth made during the second half of the 1970s have been surpassed. Even the apparently optimistic forecasts of the WOCOL group, developed in 1978 and criticised by many as an outright expression of the coal lobby, turned out in many cases to be quite conservative [2]. The comparison between WOCOL forecasts and attainments shown in table 2 does not account for the poor showing of the iron and steel industry throughout this period and therefore understates the situation. Only for the United Kingdom, with costly coal and an abundance of relatively cheap oil and gas resources, are WOCOL's forecasts, based on the National Coal Board's understandable optimism, wide off the mark, again indicating a continued general failure to appreciate the importance of economic factors in the substitution process. The poor showing of Australia and Poland with respect to forecasts in 1982 are due respectively to union miners' strikes and civil turmoil causing mine closures.

To appreciate the full implications of the incipient new trend it is necessary to distinguish between steam coal and metallurgical coal. Due to overproduction problems in the iron and steel industry, related to slower than expected economic growth, the market for metallurgical coal

TABLE 2 — *Coal production and consumption in 1982: comparison between WOCOL forecasts* (1) *and attainments* (Mtce).

country	1977	1982 forecasts (2)	1982 attainments
production			
Australia	75.7	112.7	92.0
Canada	23.0	36.4	31.4
Germany Fed. Rep.	120	124.9	127.7
India	71.8	106.0	126.1
Indonesia	0.15	0.6	0.5
Japan	17	17.6	16.6
Poland	186.1	244.7	192.3
United Kingdom	108	108.7	99.9
United States	557	652.8	686.7
other OECD	38	44.5	50.9
South Africa (3)	73	107.1	125.4
Rep. of Korea	12.0	9.9	14.0
Brazil	2.8	5.2	4.4
Colombia	4.3	10.8	5.6
Mexico	4.4	5.0	5.3
People's Rep. of China	506	665.3	662.3
total	1799	2252	2241.1
consumption			
Canada	25.0	35.6	32.4
United States	509	595.9	563.7
Denmark	4.6	7.8	8.4
Finland	4.3	4.4	2.7
France	45.0	38.5	38.3
Germany Fed. Rep.	102	112.3	113.9
Italy	13.5	18.5	20.6
Netherlands	4.5	7.6	6.7
Sweden	2.1	3.7	2.4
United Kingdom	109	107.8	93.4
rest of Western Europe	51.0	57.0	91.1
Japan	79.0	89.8	88.6
Australia	38.0	53.2	47.6
total OECD	987	1132.1	1109.8
total excluding U.S.	478	536.2	546.1

(1) Inferred from WOCOL forecasts to 1985.
(2) Taken from case A.
(3) Includes Africa south of Sahara.

has been repressed throughout most of the 1970s and early 1980s with many countries showing a decline. Lacking adequate data it is difficult to make accurate assessments of steam as opposed to metallurgical coal developments in the recent historic period. It is doubtless, however, that the attainments in total coal markets substantially understate the success of steam coal in the period considered. Particularly in the case of international coal trade, where metallurgical coal represents about 70% of the market, attainments over the last few years are liable to misinterpretation. Thus internationally traded coal increased from 195 Mtce in 1977 to barely 205 Mtce in 1982, substantially below forecasts of either the IEA or WOCOL made in 1978 [3]. However, the steam coal component of this trade can be estimated to have increased from 64 Mtce to 85 Mtce in the same period, a figure essentially in line with most forecasts made in the late 1970s.

One of the major arguments against rapid coal development has been the lack of an adequate international transport and marketing infrastructure. The quantities of coal that have entered international markets are still too small to say whether or not international integration of the coal chain from mine mouth to end use will provide problems to coal expansion in the future in countries without significant coal resources. As a number of studies, including WOCOL, tried to point out, the institutional and political nature of many of the processes involved in setting up the massive coal chains required in the future development of coal, pose severe limits on what the market alone is capable of achieving without substantial political intervention.

Most of the increase in coal production and use witnessed in the last few years has come from existing mines. Future growth at the levels considered necessary to sustain future economic growth in the world as a whole will require the opening up of a large number of new mines. The amount of capital involved in opening up a large mine of the size required to contribute significantly to world coal production at competitive prices, is so large that few investors are ready to provide financing without the certainty that the coal will effectively find a market. While the extraordinary success of coal in its first few years of revival has provided a basis for renewed faith of coal investors around the world, declining oil prices have more recently checked the excessive enthusiasm of the late 1970s. Though most accept the fact that oil prices are unlikely to decline very substantially into the future, it can be appreciated that mining authorities and mining companies prefer long-term commitments before setting off on ventures which still do not have the blessing of a long standing market.

Where direct government-to-government deals are not directly involved, investors are anxiously waiting for sufficient coal based power system expansion plans to get under way before they proceed to open new mines and expand coal transport systems. There are, of course, exceptions, such as the case of Colombia, discussed below, where coal development for the export market has been pursued as a matter of national energy and economic policy. Apart from these isolated initiatives, however, it is possible that lack of faith in the market on the part of producers will eventually slow down coal expansion as requirements move towards existing production capacity. To the extent that this will lead to a relative increase in coal prices, it may lead to a negative effect on coal use, at least in the short term. There is no doubt, however, that the future of coal is assured in sustaining energy and economic growth throughout the world as a whole in the longer period to come.

2. *Coal in the developing countries*

Where in all this are the developing countries? With the exception of a few countries such as China and India, developing countries are not exceptionally well endowed with coal resources. According to the 1980 Survey of World Energy Resources of the World Energy Conference [4], developing countries including the People's Rep. of China and the Dem. Rep. of Korea, possessed 15.9% of geological resources of hard and brown coal and 19.6% of the technically and economically recoverable reserves. Excluding China with the third largest coal resources in the world, these percentages reduce to 3.5% and 8.0% respectively. In terms of coal resources per unit land area and per inhabitant the difference between developed and developing countries is abysmal with the exception of Botswana and Swaziland, as indicated in table 3.

The apparently strong correlation existing between degree of economic development and availability of coal resources may be coincidental but has led many to wonder whether unavailability of coal resources has provided a hindrance to early development of today's developing countries or whether scarce coal resources are only a consequence of low levels of exploration for coal in the developing countries. Certainly the unattractiveness of coal compared to oil in the period of low oil prices and the ample availability of coal in developed countries due to a century or two of

TABLE 3 — *Coal resources and reserves in the developing countries* [1].

country	geological resources (Mtce)	recoverable reserves (Mtce)	density of reserves (mt/km²)	reserves per inhabitant (tce)
Africa	*125594*	*7369*	*618*	*25.7*
Algeria	66	43	18.1	2.27
Botswana	107000	3500	6076	4375
Burundi	250		—	—
Central African Rep.	1	1		0.43
Egypt	25	13	13.0	0.31
Ethiopia	1		—	—
Malawi	25	12	101	1.99
Morocco	100	50	109	2.48
Mozambique	395	240	307	19.9
Nigeria	1045	132	142	1.56
Ruanda	1000		—	—
Swaziland	5020	1820	104802	3228
Tanzania	1804	200	212	11.0
Zaire	600	600	257	20.8
Zambia	154	24	31.9	4.25
Zimbabwe	8108	734	1879	106.5
America	*48049*	*4658*	*262*	*15.0*
Argentina	7782	156	56.2	5.62
Brazil	12707	910	107	7.69
Chile	4726	924	1221	83.2
Colombia	9865	1029	903	39.7
Cuba	120		—	—
Ecuador	28		—	—
Falkland Is.	12		—	—
Haiti	13		—	—
Mexico	3564	1500	760	21.6
Peru	993		—	—
Uruguay	20		—	—
Venezuela	8219	139	152	9.31

cont'd

[1] Includes peat.

TABLE 3 (cont'd)

country	geological resources (Mtce)	recoverable reserves (Mtce)	density of reserves (mt/km²)	reserves per inhabitant (tce)
Asia	*1583290*	*115138*	*5427*	*50.19*
Afghanistan	512	66	102	4.14
Bangladesh	1112	242	1695	2.73
Burma	187	2	3.0	0.06
China P. Rep.	1439465	99109	10366	101.2
China Rep. of	164	109	3031	.
India	112586	13134	4009	19.5
Indonesia	16287	234	122	1.60
Iran	385	193	116	4.97
Israel	215		—	—
Korea Dem. Rep.	6650	534	4430	29.2
Korea Rep.	1231	116	1178	3.04
Malaysia	260		—	—
Pakistan	395	394	490	4.80
Philippines	133	64	213	1.33
Sri Lanka	22		—	—
Thailand	81	34	66.2	0.72
Turkey	2596	757	697	17.03
Vietnam	1009	150	443	2.77
Europe	*32429*	*11033*	*19214*	*207.9*
Bulgaria	6356	1880	16951	212.1
Romania	4506	413	1739	18.6
Yugoslavia	21567	8740	38706	391.2
Developing Countries	*1789362*	*138198*	*2668*	*41.2*
Developed Countries	*9394338*	*555002*	*10329*	*512.6*
World	*11183700*	*693200*	*6609*	*158.0*

past exploration and development were determining factors in directing international mining companies away from exploration activities in the developing countries. Given these circumstances it may well be that there are good chances of increasing the resource base with further intense exploration in the developing countries. If the experience of the last 10 years is significant, this may take a very long time, however. With few notable exceptions, such as Indonesia and China, little or no exploratory work has been undertaken in the developing countries during the last decade since the first oil price shock, and most of the coal resource increase, which was not due to reevaluation based on the higher coal prices, occurred in developed countries such as Australia. The readjustments in resource estimates in the recent period can sometimes be confusing. Thus, due to careful reconsideration of its coal resources, India substantially increased its estimates of geological resources and decreased the estimates for reserves, which explains the negative change for developing countries as a whole in table 4.

It is possible to identify five different types of basic coal strategies, depending on a country's oil, coal and forestry resources:

— domestic coal production as a substitute for imported oil;

— domestic coal production by oil exporting countries to free oil for export;

— coal production for export;

— coal imports to replace oil imports;

— coal development or imports to reduce deforestation.

Developing countries vary widely with regard to the importance

TABLE 4 — *Estimates of coal resources and reserves* (Mtce).

year	geological resources	technically and economically recoverable reserves
a. *Growth in resources and reserves 1974-80*		
1974	8603	473
1976	9045	560
1978	10125	636
1980	11062	687
b. *Contribution of developed and developing countries to increase in world coal resources in 1978-80*		
developed	841.4	79.7
developing	95.6	−28.2
total	937.0	51.5

of coal in their development depending on the quality, size and location of coal resources, availability of capital and alternative energy resources such as oil and hydropower. Some have relied on coal for as long as two centuries, for others coal is a complete novelty. The extent to which these strategies are emerging in major developing countries and regional aggregates is briefly reviewed in the following.

People's Republic of China

China's coal production surpassed that of the USSR sometime during the 1970s and is now second only to that of the United States. China has also been challenging the United States as the world's largest coal consumer during most of the last decade and though the battle is not yet won, China seems to be in a good position to become leading world consumer during the 1980s.

Though China is well endowed with oil and hydropower resources, its future economic growth will depend essentially on coal, by far its major energy resource. Geological resources estimated in 1980 amounted to 1439 Gtce, making China the world's third largest coal bearing country after the USSR and the USA. Its proven resources amounted to 99 Gtce of mainly bituminous coal and anthracite which, at today's production of 662 Mtce/yr, give a remaining static lifetime of 150 years. Given its enormous coal resources it is not surprising that almost 80% of its primary commercial energy consumption is based on coal, with oil at 16% and the remaining 5% distributed between hydropower and natural gas. In 1977, the last year for which reliable data are available, coal consumption was concentrated in industrial boilers, process heat and metallurgy (50%). Roughly 18% went to residential uses while another 18% went to electric power generation. Coke ovens (10%) and railroads (4%) accounted for the remaining consumption.

Coal use during the 1970s has been expanding rapidly as part of a Government policy to increase energy supplies for development and to liberate oil for exports as hard currency earner. Thus coal consumption between 1972 and 1982 increased at an impressive average rate of 4.0%. Emphasis also on increasing oil production allowed oil exports in 1982 amounting to about 19 Mt while coal exports reached almost 7 Mtce.

Though China's energy policy has been in a state of flux following the various political changes occurring during the last decade, it now appears to be quite clear that the country is intent on maximising coal production and coal as well as oil exports as a basis for sustained economic growth. A measure of the firmness with which China is pursuing its policies is evident from the increasing number of joint coal development projects with multinational energy companies as opposed to earlier policies of importing just hard technology. The acute interest in developing coal exports is evident from the railway expansion now under way connecting major coal bearing regions, such as Datong, Xinxiang and Shanxi to the eastern ports of Qinhuangdao and Shijuso. Looking further ahead, China is also seeking joint ventures in gasification and liquefaction development. The country is now planning to reach a level of production of 1.2 Gtce of coal in the year 2000. Considering the past performance (a doubling of production in just 15 years) and the level of production presently achieved (almost 700 Mtce/yr) this target should be easy to reach or even surpass.

India

India's coal resources are about an order of magnitude smaller than China's, but nevertheless the second largest in the whole developing world. With 104 Gtce of geological resources India contributed barely 1% to total world resources estimated in 1980. Compared to most countries, however, India's coal resources tend to be more shallow and mineable so that proved recoverable reserves are a considerably higher proportion of geological resources than in the case of China (12.6% against 6.9%) and contribute almost 2% to world proved recoverable reserves.

Despite this relatively favourable situation and tbe lower population pressure on coal resources, India does not appear to be aiming to expand its export capacity for coal as a source of hard currency earnings. A present consumption on the order of 130 Mtce/yr and plans to expand this to 400 Mtce by 2000 imply a dangerously short lifetime of 23 years at the end of the century. Though India was one of the few countries along with China to increase its assessment of the resource base and the country seems quite likely to double its proved reserves by the end of the century, it obviously has fewer possibilities to aim for an export oriented strategy and is therefore concentrating on developing its coal for internal use.

Coal plays a well established role in the Indian economy since production began in remote 1774. Today India's modern economy is second only to China's and North Korea's, among developing countries, in terms of the contribution of coal to total energy requirements, which amounts to almost 70%. This coal is used mostly to generate industrial process heat (28%), to produce electricity (33%) and in iron and steel production and other metallurgical processes (23%) with 16% going to households and commercial uses.

After nationalisation of coal mines in the early 1970s, considerable advances were made in mining technology which allowed a remarkable increase in coal production from 77.2 Mtce in 1973 to 130 Mtce a decade later, or an average annual growth rate of 5.4% per year. Such an achievement can be repeated with recourse to intermediate mechanisation, striking a balance between manual applications and higher capital and high productivity technology. About 90% of underground production still comes from conventional Board and Pillar technology, while it is expected that over the next decade as much as 20% of production will be taken over by Mechanised Board and Pillar and 33% by longwall technology [5]. Realising the importance of extending its resource base, India is taking active participation in research in such techniques as underground gasification, which can significantly increase recoverable resources.

Indonesia

A special case is that of Indonesia, an OPEC country with substantial oil resources, but also a country with a large population (fifth in the world with almost 150 million inhabitants), a rapidly growing modern sector and very ambitious modernisation plans. It has been evident for some time that under current trends in domestic oil consumption, Indonesia is likely to become an oil importer in the late 1980s or early 1990s. Coal development in Indonesia is therefore of crucial importance in order to extend oil exports and precious foreign currency earnings as long as possible into the future.

Indonesian coal production was very quick to respond to the change in relative coal and fuel oil prices after 1974. This country's coal production had been declining from a maximum value of 2 Mt reached in 1941 to a threshold value of about 150-200 thousand mt in the early 1970s. Beginning with 1977, production picked up again very rapidly tripling to over 600 thousand mt in just 6 years. Most of this growth was, however, connected with the export market, since very low subsidized domestic oil prices discouraged any significant increase in domestic coal consumption. Indonesia is, indeed, one of the few countries where there has been essentially no conversion of cement plants from oil to coal during the last 7 years or so.

It was only towards the end of the 1970s that the Indonesian Government began officially to realise the limitations of its oil resource base and to look for diversification policies which would allow it to extend its lifetime. Hydropower is abundant in Indonesia, but far from the main load centres so that the principal short term alternative is coal. Plans for a large coal fired electric power project based on Sumatra coal at Suralaya in Western Java were set down in 1978. The first two units of Suralaya are due to go on stream in late 1984. Due to delays in the coal mining and transport infrastructure necessary to convey 1 Mt of coal each year from the Air Laya mine to Suralaya, coal required to fire the plant will initially be shipped from Kalimantan or, if necessary, even imported.

Realising the importance of appropriate market prices in implementing energy strategies, the Indonesian Government has very recently introduced dramatic increases in domestic oil prices to reflect the long term costs of alternative resources. With these changes effective in the first half of 1984, many industries, including cement manufacturing, are now looking very seriously at the possibility of substituting coal for oil in process heat and industrial boiler use. Moreover, a large part of the future thermal power development programme is to be based on coal. As a result of all these actions, from a very timid policy in the late 1970s, the Government of Indonesia is now launched on a very strong coal development policy which is expected to bring total coal production to 27 Mt in 1995, of which 21 Mt for internal consumption and 6 Mt for exports.

In relation to this a strong exploration programme is also under way to develop the resource base. An important part of this programme is the very interesting production sharing agreements which have attracted a considerable number of mining ventures. The importance of an appropriate environment to attract foreign capital is emphasized by the fact that with just 2 years of initial exploration activities, from 1982 to 1983, the coal resource base of Kalimantan has been increased by 200 Mt of good quality cheap surface mined coal which is already finding an easy entry in the Asian market. The main problem to development in the short term seems to be not the coal resources or their mining, but the infrastructures required to deliver tbe coal from the mines to the load centres. In almost every case the lead time for basic transport development tends to be a few years longer than the time required to develop the associated mine.

Rest of Asia

All other countries of Asia have known coal resources at least one or two orders of magnitude lower than India's. Strategies with respect to coal development in these countries vary substantially as a function of population pressure and degree of economic development as well as availability of alternative energy resources. Thus the Democratic Republic of Korea with about 33 tce of proven coal reserves per capita, (more than twice the value of India, and a third the value of China), presently has a policy of relative self-sufficiency based largely on coal. On the other hand the Republic of Korea with only 3 tce of proven reserves per capita is undertaking a major programme of coal imports expansion to sustain its very vigorous and growing economy.

The Republic of China (Taiwan) belongs to the same category of countries as the Republic of Korea with limited coal resources and a buoyant economy which they cannot hope to sustain and remain competitive on world markets on the basis of oil energy inputs alone. All such countries, including Hong Kong, Malaysia, the Philippines, Singapore and Thailand are going in for a programme of increasing reliance on imported coal particularly in connection with electric power generation.

Countries in this area with especially large programmes are the Republic of Korea and Taiwan which, according to most recent intelligence, plan to increase their combined coal imports from 12.8 Mtce in 1980 to 29.5 Mtce in 1985, 46 Mtce in 1990 and 61 Mtce in 1995, largely to meet expected growth in electricity requirements. That these plans are very likely to be realised is evident from the programmes that are already under way in these two countries. The capacity presently under construction and due to come on line before 1987 amounts to 3.5 to 4 GW. Both countries have, moreover, undertaken ambitious plans to expand their coal port unloading capacity. Korea has just recently inaugurated two new coal terminals at Gojeong and Samcheopo capable of accommodating 150 thousand DWT vessels and unloading over 5 Mt/yr of coal. By late 1984 port capacity in Korea will allow entry of 12 Mt/yr of steam coal for power generation. Realising the importance of securing long term flows of coal from mine mouth to power plant, Taipower of Taiwan has taken part in joint ventures for coal mine development in South Africa, Australia, the United States and Canada.

Though coal imports are basically directed to iron and steel production and power generation, local conditions can favour utilisation also in other sectors. Thus Korea's policy of basing its industrialisation on industrial parks with common transportation, energy and housing lends itself particularly well to centralised use of coal-fired industrial boilers for space heating, process steam and electricity generation with remarkably low distribution losses. In the residential sector of Korea, continued use of clean burning anthracite briquettes adds another 20 Mt/yr of coal consumption for the rest of this century, most of which is, however, produced locally.

The other countries of Asia generally have less vigorously growing economies, are at a lower stage of development with a smaller urban and industrial sector, or have alternative energy resources such as hydropower or oil, so that coal development does not for the moment play a dominant role in energy policy.

Central and South America

Of all countries in Central and South America, Argentina, Brazil, Chile, Colombia, Mexico and Venezuela have significant geological coal resources in excess of 1000 Mtce. Countries with proven reserves in excess of 20 tce/capita are Chile (924 Mtce), Colombia (1029 Mtce) and Mexico (1500 Mtce). Coal consumption in the area as a whole is quite low, being less than 10% of total fuel consumption. Only in Colombia, where coal is a frequent outcropping and has been locally used in households and industry for many years, does coal contribute significantly to the energy balance (25%).

The prospects for coal development in Central and South American countries are highly dependent on the availability of oil and other energy resources with which the region is blessed. At one extreme are countries like Chile with scarce oil resources. Chile imports today about 70% of its oil needs and, not surprisingly, it is making a substantial effort to develop its appreciable coal resources. Very early after the first oil price shock, Chile began converting its copper facilities and power plants from oil to domestic coal and plans to continue on this path into the future.

At the other extreme are countries like Venezuela and Mexico with large and cheap oil resources. Current energy programmes prepared by the Mexican Government seem to be aiming at developing coal in substantial quantities with the objective of both exporting coal and liberating oil for future exports. Venezuela with larger oil resources is less interested in developing its coal resources although some coal development is taking place particularly in relation to its iron and steel industry.

In between are countries like Peru, Argentina and Ecuador with little coal but with fairly large quantities of oil. These countries have no problems in meeting their energy requirements with oil and give little emphasis to coal development in general whether through local mining or imports. Only Argentina is making some effort to develop its limited coal resources for local consumption.

Population pressure and a highly dynamic economy put Brazil in a class apart though it has substantial resources of both coal and oil. The huge energy resources required to fuel a mostly urban population of 120 million growing at 2% per year have required massive energy development efforts on all fronts. Most of Brazil's coal reserves are located in the state of Rio Grande do Sul. Such reserves have very high ash quantities on the order of 45-55%, which makes washing and transportation of the coal to some of the more distant areas of the country practically an energy loss situation. This problem may be resolved in the future by blending locally produced coal with very high quality Colombian coal imported from the new Cerrejón mine. Through this expedient Brazil is now examining the possibility of exporting some of this upgraded steam coal to Europe.

Colombia is the only country in Central and South America which bas an early history of coal development. In many places coal occurs as an outcropping and it has been in use for many decades in local households and particularly in industry. More recently, some power plant development based on coal has taken place in the Central and Atlantic Coast systems, areas far from the basic grid and without hydropower or other significant local energy resources. Hydropower is so abundant in Colombia that coal can play only a very limited role in meeting the country's power requirements. Despite extensive and successful development efforts, Colombia's oil resources are, moreover, unlikely to satisfy oil products requirements in industry and transport for much longer than a decade or so. Colombia's policy of favouring coal development for exports rather than for internal use is dependent on these two basic factors. The country seems to be bent on a future of full electrification based on cheap hydropower resources while oil will be increasingly ousted from all markets except transport, and coal will be privileged mainly for export earnings. Government estimates for 1995 indicate 2.1 Mtce will be consumed by electric utilities, 1.9 Mtce in iron and steel, 5.9 Mtce in industrial process heat (particularly bricks and cement) and about 0.2 Mtce in households for a total of 10.1 Mtce. This is to be compared with a forecast of 18 Mtce of steam coal exports in the same year.

What is perhaps surprising is the determination with which Colombia has been able to undertake its coal expansion programme. In 1978 its plans to develop the two Cerrejón mining projects and a 150 km railroad to Bahia Portete on the Guahira peninsula looked like pure theory. Five years later the Zona Central was producing coal, the access road from mine to port was completed, and railroad construction was under way. Port dredging was practically complete and the coal pier was well on the way to termination. Colombian coal from the first Cerrejón project is now seeking world markets, which should not be too difficult to find, given the high quality of the coal.

Africa

Africa as a whole, excluding the Republic of South Africa, has geological coal resources amounting to 126 Gtce of which 7.4 Gtce, or 5.9%, are considered proven recoverable reserves. Countries with over 100 Mtce of proven reserves are Botswana (3500 Mtce), Swaziland (1820 Mtce), Zimbabwe (734 Mtce), Zaire (600 Mtce), Mozambique (240 Mtce), Tanzania (200 Mtce) and Nigeria (132 Mtce).

With the exception of Nigeria, most of these countries have limited or negligible oil resources and coal is therefore likely to have important future development potential. Prospects for immediate or early development of this potential are, however, quite slim. Practically, none of these countries have developed a large enough demand to justify extensive coal development for domestic consumption. The small size of the electric system usually does not justify unit capacities greater than 50 MW which substantially reduces the competitiveness of coal vis-à-vis other energy resources. Substitution of coal briquettes for fuelwood in household uses is deterred by the high distribution costs and small buying power of the largely rural population. Requirements for foreign currency can be satisfied with relatively low levels of production. Transport infrastructures are, moreover, inadequate to cope with large quantities of coal or would require substantial expansion and development. All in all these factors militate heavily against early development of coal in most African developing countries. It is significant to this effect, that only in the case of Nigeria, the most developed of these countries (but also the one with the least coal resources), has there been any serious attempt to increase coal production effectively. The coal, which would be slated mainly for exports, is not likely to compete well on international markets, however, because high production costs make the coal unattractive to foreign buyers.

Production in developing countries of Africa as a whole reached little above 10 Mtce in 1982, of which 3 Mtce were exported to other regions. Most of this production took place in Zimbabwe with almost 5 Mtce, followed at a distance by Mozambique and Swaziland each with about 1.5 Mtce, while Nigeria and Zambia produced around 1 Mtce each. The coal went mainly into copper smelting, cement and fertilizer production and railroads. Domestic consumption is very limited because of strong competition from traditional fuels. Some forecasts indicate growth at rates greater than 5% per year beyond 1985, with about one third of the coal being exported. Besides the problems discussed above, there is also the poor quality of the coal in most of Africa, which will tend to reduce its competitiveness in international markets.

3. *Coal and development in the developing countries*

If the last 6 years of coal development activities in many developing countries are a prelude to future growth, then there seems to be no doubt that coal has great prospects for these countries in the future. All countries that have significant potential for coal development have reacted rapidly and with determination to the inversion in coal and oil price trends established in the 1970s.

Countries like Chile and India with limited oil resources but ample coal resources have reacted to the prospects of crippling oil imports by coal development for domestic use. Other countries like Indonesia, blessed with ample and diversified energy resources, and relying on oil exports as a principal source of foreign exchange for development, have begun to exploit their coal resources in order to liberate as much oil as possible for exports. Other developing countries like Colombia, China and again Indonesia, with both oil and coal resources are also actively looking upon coal exports as a source of foreign exchange. Finally, a large number of middle income countries such as Korea and Taiwan with no oil but strong development potential are embarking on large programmes of coal imports as a substitute for otherwise expensive oil.

Problems such as the implementation of coal chains from mining to end use, which seemed to loom large on the horizon, have not been as serious for the developing countries as they have been for the industrial countries. This may be due to the smaller coal volumes involved in the single countries and the relatively small share of these quantities in international trade. Most of the developing countries with a serious need to either export or import coal, or simply to produce coal for domestic use, are taking the right actions to ensure that coal chains are in place at the right time. Such actions range from exploration and mining witbin their own countries and joint ventures in other countries, infrastructure development for inland coal transport, port development and expansion for coal exports and imports, to power system planning based on coal and the conversion of cement plants and industrial boilers from oil to coal. Wben transport infrastructures are not already in place, the mine may be ready to produce and the power plant ready to be turned on a few years before the coal system is ready. These problems, though they stand out in the first period of growth, do not seem likely to seriously hamper coal development plans of most developing countries.

Financing of coal systems has proved generally to be less of a problem than previously imagined. When coal production is primarily for domestic consumption and only a small quantity is slated for exports, however, foreign equity cannot easily be attracted to fund capital requirements except on very interesting terms which many developing country governments are still not willing to grant. The role of bilateral and international financing agencies is thus likely to be important in the future of coal in developing countries. Particularly in the case of high-risk exploration activity there is a need for adequate financing mechanisms. For many developing countries in coal bearing regions even low levels of exploration activity can completely change the prospects of coal development in the space of a few years if only the funds could be set up and mining companies suitably attracted. This may not be as urgent in some countries as in others, due to different levels of demand and capacity to absorb foreign exchange earnings from exports. Nevertheless a number of coal development projects have recently been financed both through the World Bank lending programme and many bilateral agencies showing the increasing interest in this field of development.

The ultimate question is to what extent is coal able to provide a basis for continued economic growth in the developing countries? The data in table 5 on coal production and consumption refer to 1982, the last year for which reasonably homogeneous data are available for all countries considered. From this table it emerges quite clearly that even countries like China and India with high levels of production have today still appreciable reserve lifetimes. Other countries because of presently low levels of exploration of reserves have even longer lifetimes stretching to 1000 years and over.

The present ratio of reserves to production as a measure of self sufficiency is only partly indicative, however, considering the low levels of per capita coal consumption and energy use in general, a factor 10 times lower for the developing countries than for the developed countries as a whole. Assuming moderate levels of growth in coal use and production in developing countries, say 4% over the next two decades (6% excluding China), and that proven reserves remain constant (which means a rate of addition to proven reserves over the next 20 years equal to the rate of exploitation) then the average static lifetime of coal reserves in the developing world will decline still only to 80 years or so. Only in a few countries do these assumptions lead to short reserve lifetimes at the end of the century, for example India (33 years), and Indonesia (10 years).

The problem in a sense is only apparent since as the cheaper resources are mined, price increases and technology improvements will lead to more and more geological resources entering the category of proven reserves with the resource lifetime being prolonged indefinitely. Unless more cheap coal resources are discovered throughout the developing countries, however, this means that coal use will become more expensive though developments in supply and conversion as well as end use technology may help to palliate this effect to some extent.

The possible increase in energy costs is unlikely to harm the buoyant economies of middle income countries such as Korea and Taiwan, unendowed with plentiful energy resources, but with powerful export oriented economies. There is, however, the category of low income developing nations with scarce oil and coal resources for which coal development prospects can be considered generally quite slim. These countries number a total population on the order of 200 million and will in the future experience increasing energy prices on all fronts without the possibility of countering this through the development of alternative domestic energy resources.

TABLE 5 — *Production and consumption of coal in the developing countries in 1982.*

country	production (10^3 mt)	share of coal in total consumption (%)	per capita coal consumption (kce)	static lifetime of reserves (yr)
Africa	*10723*	*7.7*	*23.8*	*687*
Algeria	7	3.3	47.2	6143
Botswana	420		0.5	8750
Burundi	3	3.9	0.7	—
Central African Rep.	—	—	—	—
Egypt	—	4.9	25.2	—
Ethiopia	—	—	—	—
Malawi	—	16.7	8.2	—
Morocco	1000	13.5		50
Mozambique	1300	30.7	27.9	185
Nigeria	650	1.0	2.2	203
Rwanda	—	—	—	—
Swaziland	1400	—	1.1	3228
Tanzania	1	0.1		—
Zaire	140	14.5	10.8	4286
Zambia	1100	19.1	71.4	21.8
Zimbabwe	4702	62.4	344	156
America	*16647*	*6.5*	*75.5*	*280*
Argentina	420	2.5	43.5	371
Brazil	3929	9.4	70.8	232
Chile	1126	16.0	148	821
Colombia	5300	24.8	187	194
Cuba	—	1.0	14.2	—
Ecuador	—	—	—	—
Falkland Is. (Malvinas)	—	0.2	3500	—
Haiti	—	—	—	—
Mexico	5776	4.9	83.2	260
Peru	50	1.9	11.6	—
Uruguay	—	0.1	1.0	—
Venezuela	46	0.7	21.4	3022

cont'd

TABLE 5 (cont'd)

country	production (10^3 mt)	share of coal in total consumption (%)	per capita coal consumption (kce)	static lifetime of reserves (yr)
Asia	*800202*	*64.16*	*264*	*144*
Afghanistan	125	13.7	7.7	528
Bangladesh	—	4.4	2.0	—
Burma	34	11.1	7.0	58.8
China People's Rep.	596000	75.7	437	166
China Rep. of	1000			
India	126143	64.6	129	104
Indonesia	350	0.8	2.0	669
Iran	700	2.2	19.3	276
Israel	—	0.1	1.5	—
Korea Dem. Rep.	42000	87.2	2326	12.7
Korea Rep.	14000	37.5	532	8.3
Malaysia	—	0.6	6.0	—
Pakistan	1118	6.9	15.2	352
Philippines	247	3.4	11.9	259
Sri Lanka	—	0.1	0.1	—
Thailand	556	3.8	12.6	61.2
Turkey	11429	33.9	238	66.2
Vietnam	6500	76.4	113	23.1
Europe	*55296*	*35.2*	*1310*	*200*
Bulgaria	14735	44.2	2323	128
Romania	17704	24.0	1059	23.3
Yugoslavia	22857	48.7	1115	382
Developing Countries	*850429*	*45.6*	*218*	*160*
Developed Countries	*2124143*	*29.4*	*1774*	*262*
World	*2974571*	*32.3*	*643*	*233*

Coal in fact, is not a cheap resource to develop. Generally speaking it is the domain of industrial countries, middle income countries with strong export potential, or low income countries with very large resources and very large potential requirements. It should never be forgotten, moreover, that, although coal is less expensive today in many key sectors than is oil, it is considerably more expensive than was oil in the heyday of the oil era.

REFERENCES

[1] *L'Europe face à ses besoins croissants d'énergie*, OECE, Paris 1956.

[2] *Coal Bridge to the Future*, Report of the World Coal Study, Editor C. Wilson, Ballinger, 1980.

[3] *Steam Coal Prospects to 2000*, IEA, 1978.

[4] *Survey of Energy Resources* compiled for the 11th World Energy Conference by Federal Institute for Geosciences and Natural Resources, Hanover, 1980.

[5] J.K. Bose, *Coal, the Prime Energy Source in India: its Resources, Production Development and Certain Environmental Implications till 2000 A.D.*, 12th World Energy Conference, New Delhi, 1983.

PROBLEMS OF ENERGY DEVELOPMENT IN LESS DEVELOPED COUNTRIES

K. S. DEMIRCHIAN
USSR Academy of Sciences

Energy development promotes economic development and, in turn, by virtue of its high specific consumption of materials, greatly depends upon the capabilities of national economy. Even a highly developed country such as the U.S.S.R. may only attain self-sufficiency in energy through large investments and management efforts at the level of a national energy program, along with hard practical work on the national scale. Energy development experience of other countries likewise points to the need for national energy programs.

We made a reference to the U.S.S.R. energy program for the simple reason that the experience gained from its development could well be used by other countries. In the preparation of this program there have been developed and applied methods of combining the efforts of many Union republics for dedicated energy development, as well as methods of providing mutual assistance and of solving problems associated with the development of industries that are rather unusual for the population of particular regions; use has been made of experience accumulated in the course of overcoming professional and technology barriers caused by the fact that energy development is occurring in a country inhabited by people of numerous nationalities maintaining their original cultures, traditions and way of life. The very process of developing the program has shown that its validity depends primarily upon the availability of most highly skilled scientific and technical personnel. Therefore, of direct, if not decisive, importance was the participation in this work of the scientists from the U.S.S.R. Academy of Sciences, major specialists in the field and, especially, the fact that the work was supervised by A.P. Aleksandrov, President of the U.S.S.R. Academy of Sciences, the leading specialist in the field of nuclear power engineering. This experience shows that the development of large-scale interstate energy development programs by less developed countries (LDC) will involve overwhelming practical difficulties even if the political leaders of those countries are fully resolved to develop such a program.

With regard to LDCs, one should take into consideration a number of factors aggravating the problems of their energy development. These countries, of which there are 70 in Asia and Africa and whose population in the year 2000 is expected to reach 2.5 bln people (less China) with the prospect of growing to 3.5 bln by 2030, have no appreciable energy resources. Moreover, most of these countries are importing oil. These countries are characterized by a very low per capita income amounting to about 240 dollars per annum in 1975, which, under favorable circumstances, may increase by the years 2000 and 2030 up to 360 and 550 dollars, respectively. This is 6.5, 6 and 5 times less than the average world per capita income and 29, 30 and 23 times less than per capita income in the most developed countries. The most pressing problems faced by these countries include, apart from energy development, the most vital problem of conservation of Nature as the prime condition of ensuring the food supply. It should be taken into consideration that there will hardly be any substantial increase in the area of land under cultivation by the year 2000 (4-5% at the most), and, therefore, 1 ha of farming land will have to support about four people instead of 2.5-3. An increase in the crop capacity may be attained through the use of energy intensive technologies and will call for high expenditure, especially, of oil. For this reason, an increase of prices for liquid fuel will inevitably lead to increased food prices. All of these factors predetermine a low rate of growth, if not stagnation, of per capita food consumption in LDCs. Given the extremely unfavorable food supply situation already prevailing in these countries, it is evident that the domineering medium- and long-term problem facing LDCs will be that of food supply. From this standpoint, considerable importance is acquired by the search for such ways of energy development in LDCs that would not infringe upon the interests of their agriculture. This problem will be most acute for the governments of countries in South, East and South-East Asia, as well as of the poverty-stricken countries in North and, especially, Central Africa, where the amount of food available to the poorest sector of population may be reduced catastrophically. Few studies have been made heretofore into the possible effect which the availability of fresh water resources in LDCs may have upon energy development. In many of the less-developed countries, whose combined population makes up almost 25% of the world population, the fuel for cooking and heating purposes is provided by firewood 90% of which comes from lumbering. The intensive reduction of large forests will result in the rise of firewood prices and in the decrease of water resources essential for agriculture, as well as in the reduction of arable land turning to desert. At the present time, this process develops at a brisk pace, as a result of which 5 to 7 mln ha of arable land are lost to agriculture every year. Further reduction of farming land in these countries will occur due to urban growth involving a practically uncontrolled increase of metropolitan areas and population caused by the deterioration of standards of rural life.

We believe, therefore, that the problem of energy development in LDCs should be considered primarily from the standpoint of its close relation with the problem of food supply. Hence, we shall discuss below some known energy sources which, according to all forecasts, appear to be medium- and long-term ones.

The various estimates of the world fossil fuel resources differ; however, all of them more or less agree as to the order of magnitude and may be quoted as follows: for coal, 10 to 12 trillion tons; for oil, 300 to 400 billion tons; for gas, allowing for possible discovery of new deposits, up to 200-300 trillion m^3. The LDCs' share of these resources amounts to: coal, about 200-250 billion tons (ca. 2%); oil, 30-35 billion tons (ca. 10%); gas, about 16 trillion m^3 (5-6%). Unfortunately, even these resources are distributed rather unevenly. For example, almost all of coal resources are concentrated in 8-10 countries (India, 50-60 bln tons; South Africa, 50-60 bln tons; Brazil, about 10 bln tons; Colombia, about 8 bln tons; Zimbabwe, about 7 bln tons; Chile, about 5 bln tons), while oil and gas are found in even fewer countries. While so doing, even at a relatively low but optimistic rate of energy consumption growth (2.5 bln tons by the year 2000 and 3-4 bln tons by 2030) in LDCs, cumulative energy consumption in these countries by the year 2030 will amount to about 75-80 bln tons of oil and 55-60 bln tons of coal. For this reason, most of these countries will continue to import fossil fuel. Consequently, the majority of LDCs, the population of which will make up 40-43% of the world population (about 2.5 bln out of 6 bln) by the year 2000 and 45-50% (about 3.5 bln out of 7.5 bln) by 2030, will not be able to rely on domestic fossil fuel resources as their main source of energy.

The relatively rapid rate of economic growth of industrially developed countries in the fifties-sixties was largely due to the availability of a cheap energy source such as oil. The rise of oil prices in the seventies caused a sharp drop in the rate of economic growth in all countries with market economy. In this connection, the unavailability of the most versatile energy source such as oil will undoubtedly aggravate the problem faced by LDCs inasmuch as it is impossible to develop the industry and infrastructure in the absence of the most efficient kinds of energy such as electrical power and motor fuel. It appears impractical for LDCs to rely on using part of the trade balance for buying fuel in view of a faster rise in the price of technology bought by LDCs from the West as compared with the increase of the cost of raw materials and salaries in LDCs. This very unfavorable situation is inevitably aggravated by the arms race which, on the one hand, tends to increase the overall price of the civil equipment being imported and, therefore, puts an indirect burden on LDCs and, on the other hand, forces LDCs to take part in this senseless process forced on them from without and spend their meager resources for buying expensive military hardware. Because of this reason, one of the major conditions for the development of LDCs is the halting of the arms race.

The U.S.S.R. experience shows that it is impossible to master sophisticated technology and acquire high skills on a massive scale without long-term and direct mutual aid between Union republics. Of extreme importance appears a careful and cautious attitude towards local traditions and way of life which often come in conflict with the requirements of technological development. From this standpoint, rather characteristic are the problems associated with the development of electrical power sources based on the use of diametrically opposite technologies such as nuclear power plants and small-scale hydroelectric power stations.

The development and operation of large nuclear power plants designed to service several countries will call for large capital investment while requiring a limited amount of highly qualified personnel the training of which does not appear to present a serious problem. On the other hand, small hydroelectric power plants, of which there may be many, will require large numbers of relatively low-skilled attendants, whose training likewise presents no problem. The experience of the U.S.S.R., where a large number of rural hydroelectric power stations were built over a period of 10-15 years, shows that this way of producing electrical power for the supply of rural areas may be quite acceptable for LDCs both economically and technologically. It seems to us that, in combination with large interstate nuclear power plants designed to supply electrical power to major cities and industries, small hydroelectric power stations are capable of covering almost the entire range of electrical power consumers in LDCs. The problems of safety at nuclear power plants do not fall within the subject of this communication; however, it appears fit to stress the following point. Multilateral intergovernmental agreements on the construction of nuclear power plants are only possible under certain political conditions in the region ensuring peace and accord between the partners, which may serve a basis for accident-free operation of nuclear power plants. The realization of this truth might serve a positive influence in stabilizing the interstate relations as well.

On the whole, the trend towards the use of nuclear power plants and utilization of hydroresources for satisfying the LDCs' needs in electrical power is in complete agreement with the principal tendencies in the long-term world energy development. All forecasts, with the exception of the dedicated forecast oriented to the use of solar energy, propose to meet the energy deficit through the use of nuclear energy. The development of nuclear power engineering will require considerable financial efforts. We believe it next to impossible to cover these expenses through credits from developed countries because, as shown by practice, the freely varying bank rates render the credit interest yet another means of increasing the debts. New economic relations should be established that would provide for the rendering of effective and unburdensome aid. Without this, there will be no proper basis for the realization of nuclear power engineering development programs in LDCs.

The countries less developed economically and lacking resources of traditional fossil fuels are, as a rule, characterized by rather favorable climatic conditions in which renewable sources of energy may play a more important part, such as water power, energy of solar radiation, energy of biomass, energy of wind, tidal energy, as well as the energy of the temperature gradient of the world ocean and, in some cases, geothermal energy.

An important feature of most of the renewable sources of energy is their dispersion. It is this very feature that is of special significance to LDCs where the problem of decentralized energy supply, will stay urgent for quite a long time.

Historically, some of the renewable sources of energy have long been in use. Such sources include the energy of wind, water power and agricultural waste. However, serious modern studies of the problems of their wholesale utilization were started only recently — since 1973, following the ill-famed oil crisis. Impressive advances have been made over a short period of time, especially in the field of utilization of solar and wind energy, as well as in the studies of scientific principles of bioconversion. These advances are indicative of the high potential held by the renewable sources of energy. These studies, however, have also shown that this energy is far from being free and can only be harnessed as a result of considerable financial and technological efforts, which should be borne in mind when evaluating the importance of such sources to LDCs. Based on these considerations, we shall now discuss some peculiar features of some of the most abundant and promising renewable sources of energy.

Solar energy

All of the renewable sources of energy, with the exception of geothermal energy, are based on the energy of the Sun. Strictly speaking, the fossil fuels such as oil, gas and coal likewise present the product of the accumulation of solar energy. It is only a tiny fraction of the annual flux of solar energy amounting to 178,000 TW/yr that is utilized directly. This energy is dissipated, it is reflected by the clouds and absorbed by the atmosphere and, therefore, its average annual density on the face of Earth, even at the Sahara level, does not exceed 250 W/m^2 (ca. 6 kW-h/m^2) on condition of 4,000 hours of irradiation per year. In the medium latitudes this power density is lower and does not exceed 100 W/m^2 at 1,500 hours of irradiation.

With due regard for the fact that the total amount of solar energy by land reaches the value of 25,000 bln tons of coal equivalent, this energy may be considered unlimited. It is only a minor fraction of this energy amounting to 1 bln tons of coal equivalent, however, that is readily accessible economically; it is used mainly for heating purposes.

In the long-range perspective, consideration is given to two basic processes for the conversion of solar energy, not counting its direct utilization for generation of thermal energy, namely, conversion to chemical energy carriers (such as hydrogen) and direct conversion to electrical power. Regarded as the cheapest is thermal energy obtained as a result of absorption of solar energy by special collector surfaces. Two types of collectors may be singled out, i.e., plane and focusing ones. The efficiency of the cheaper plane collectors reaches 30-60%. Due to a low temperature of the heat transfer agent, they are designed for decentralized generation of low-grade heat and may be used in LDCs for heating and other domestic needs. Higher temperatures may be obtained with the aid of focusing collectors by using mirror surfaces. Such collectors help attain high temperatures and may be used, for instance, in solar power plants for cooking purposes. It should be stressed that both the collectors and mirror systems focusing the energy of the Sun are rather expensive and will hardly be getting any cheaper in view of the rising cost of raw materials. In spite of the zero fuel component, the cost of electrical power generated from solar energy in plants utilizing the conventional thermodynamic cycle will be high because of large capital investment exceeding that for nuclear power plants. Rather attractive is the possibility of direct conversion of solar energy to chemical and, especially, to electric energy using the photoelectric effect. Although the capital costs involved in the construction of such plants will be substantial, this process may, in the long run, provide an important source of electrical power for LDCs. Finances and education will be the two principal limitations.

Water power

Water power is the most widely used and attractive variety of renewable sources of energy.

The overall water power potential of the Earth that is technically available for utilization is estimated at 2.2 bln kW with a possibility of producing energy at the level of 19.10^{12} kW-h/yr. Currently utilized is but 5% of these resources.

The main factor checking the development of hydroelectric power plants resides in their high relative capital requirements. It is believed by a number of experts that cost-effective hydroelectric plants nowadays are those characterized by the cost per installed kilowatt of 800 to 1,500 dollars. In view of the rising prices for traditional fuels, this level may rise to 3,500 dollars by the year 2020.

Although water power is regarded as "clean fuel", the construction of hydroelectric power plants sometimes involves ecological problems. It is assumed that, because of a limited number of available sites fit for construction, ecological considerations, increasing demand for water for other uses and competition from nuclear power plants, the relative share of water power in the world electrical power generation will shrink to 12-15% by the end of this century as against 23% in 1975. While so doing, the share of hydroelectric power in the primary energy balance will stay roughly unchanged at 5%. Hydroelectric power plants appear very attractive for use in relieving peak loads and equalizing fluctuations in demand for electrical power, as well as for setting up energy reserve.

Special attention should be given to mini-hydroelectric power plants with a power of under 5 MW designed to service decentralized consumers, mainly in developing countries.

Geothermal energy

Geothermal energy is the internal heat of the earth. By total resources of geothermal energy we mean the heat stored in rocks to a certain conventional depth, which can be released if the rocks are cooled to a yearly average temperature on the earth's surface.

Various estimates are based on a depth from 3 to 10 km, and the resources differ depending on the assumed depth.

Thus, for example, the value of 10^{24} kJ is reported in the literature for the depth of 10 km, while the heat suitable for production of electric power stored in the earth to the depth of 3 km is estimated at $8 \cdot 10^{17}$ kJ.

There are two principally different sources of geothermal heat as follows:

— hydrothermal and steamthermal sources, representing hot water and steam (both dry and wet) having a temperature from several tens of °C up to 300-350°C;

— petrothermal sources associated with the heat of hot dry rocks.

In the latter case, in order to extract heat, one must make artificial circulation systems, i.e. porous or fissured structures which would allow the water pumped into a well to be heated due to heat transfer and to be extracted from another well. The estimates show that a geothermal power plant of 1 million kW output having efficiency 11% and operating life 30 years would require 125 km^3 of dry rock involved in heat transfer.

The first pilot plants based on the use of hot dry rocks are expected to be put into operation by the end of this century. Some practical results have been obtained hy now in the utilization of hydrothermal and steamthermal sources to produce heat and, to a lesser extent, electric power. The total installed capacity of geothermal power plants all over the world is only 1400 kW. France, Hungary, Iceland, Bulgaria, Romania, Mexico, USA, USSR and a number of other countries have gained experience in the construction and operation of systems of geothermal heat supply. In the USSR alone, there are several hundreds of such plants supplying underground heat to residential and institutional buildings, greenhouses and hotbeds, health-resort and sports complexes in the cities of Tbilisi, Makhach-Kala, Kizliar and Cherkessk.

However, the scope of practical utilization of geothermal heat conforms neither to the existing reserves nor to the ever increasing energy and heat demands. The major difficulties here are associated with the problems of deep drilling, corrosion and salt deposition in pipe-lines as well as the ecological demand for repumping saline water down the lorehole into the strata. Geothermal energy will certainly be increasingly utilized.

Biomass energy

As follows from the reports presented at the 2nd World Conference on Energy, there exists an evident tendency to increase the utilization of biomass to produce power. The primary source of biomass is the sun or, more accurately, about 0.2% of the incident solar radiation used in photosynthesis.

Several methods for obtaining power from biomass can be employed:

a) By direct combustion of firewood and all kinds of vegetable residues. Transportation difficulties as well as the dispersive nature of this source of power are the cause of insufficient attention paid to this traditional method, although it is still making nearly as great a contribution to power generation as is expected to be obtained from all kinds of biofuel.

b) By producing liquid products and gases via pyrolysis. The method is being studied in Canada, where by the year 2025 about 4% of the country's energy needs are expected to be met by using this method.

c) By producing ethylene from polysaccharides. The product fuel can be used in the existing or slightly modified internal-combustion engines. The National Energy Program of Brazil is oriented in this way. In this country, 7.3 million m^3 of alcohol will be produced in 1985-1986 at 275-285 U.S. dollars/m^3, which is only slightly higher than the wholesale price of petrol, 230 U.S. dol./m^3.

d) By anaerobic processing of various organic waste products to produce biogas, i.e. mixture of methane and carbon dioxide. This way is quite practicable, and by this time rural biogas plants are operated in many developing countries having a warm climate. In India alone, more than half of the country's energy needs are met by using waste products of agriculture. Many plants of this type are operated in China.

According to the estimates made by the Indian specialists, the gas yield from 100 kgs of dry manure is 12 to 13 kgs fuel equivalent. One plant producing 100 m^3 of gas per day, from a herd of 275 heads of cattle, can meet 75% of the energy needs of a village with 500 inhabitants. Besides energy, the plant produces a high-quality fertilizer (3.5 tons per year of bound nitrogen).

The main problem of utilizing biomass at the present time is not of a technical nature, and is not associated with its availability, because on the whole the vegetation can produce an immense amount of power. The problem is caused by providing the necessary biomass suitable for utilizing in the required place at the desired price.

Most developed countries are interested in producing biogas from waste products of various processes, such as waste lumber, solid waste products of wood-pulp and wood-working plants (lignin, cooking liquid), domestic solid waste 70% of which is an organic matter. To utilize solid waste large garbage disposal plants and plants for treatment of the agricultural and food waste have been built.

Studies are being carried out related to the cultivation of "power generating" plantations of rapidly growing trees, particularly shrubs of spurge (plants of the genus Euphorbia) having much milky juice, being an aqueous emulsion of carbohydrates. Power can be produced from algae, and presently an experimental plant of this type is under construction in California. A serious revaluation of the efficiency of power generation from biomass must be made, primarily for the conditions of decentralized production. All appropriate factors, particularly the quality of the raw material, must be taken into account in each individual case. Potential uses, transportation expenses, ecological considerations, performance and cost indices, etc., must be decided by taking into account all system details, as well as regional and national features.

Naturally, the results of such a comprehensive analysis will differ, and however these results must decide on the extent and duration of utilizing the biomass.

Wind power

The sun is also the source of wind power. The presence of wind power in all places offers a large possibility of its utilization. But, when considering the questions related to the utilization of wind power the following must be taken into account, namely, time variation, low concentration in the volume unit, and irregular velocity. Today, the operation of wind-power stations at wind velocities lower than 5 m/sec is considered economically viable.

The utilization of wind power can be performed by means of wind-driven electric plants of 1 to 100 kW power output, the so-called small-scale power generation, i.e. to supply power to relatively small independent installations, mainly in agriculture (mechanization of water pumping, irrigation, desalination of water, water aeration, power supply to radio equipment, cathodic protection etc.).

This method has reached considerable development in a number of countries. Wind-power stations and systems of large wind-power stations are presently being studied. The estimates show that in most countries wind-power stations could produce up to 10% of electric power by using about 1% of their land areas.

Wind power is converted into electrical energy by means of wind turbines of various size, with a horizontal or vertical rotor. The world's largest single unit has a power output of 2 MW ("MO-I" wind-power plant in the USA). In the near future, wind-power stations of 3 MW will come into operation (WTS-I, Sweden, and Growian-I, Western Germany).

The cost of 1 kW of installed capacity is presently about 350 to 500 US dollars, including expenditures of 250 dollars per kW related to construction and operation of storage facilities. This relatively high constant cost component is actually a barrier to a large scale utilization of the wind power in the power generation industry.

Many technical, scientific and organizational problems have still to be solved.

Tidal power

Tides are caused by lunar and partial solar attraction. The technical potential of the tidal power is estimated at 1 milliard kW. On the whole, in the world there are about 25 locations suitable by their geographical situation for construction of tidal power plants (TPP), the total power that can economically be extracted being 60 to 100 million kW, which is an extremely small fraction of the total world energy balance.

Two large TPP have been constructed by now in the world, namely, the Kislogubskaia TPP of 800 kW in the USSR, and in the estuary of the Rhone in France, of 240 kW power output. Possibilities exist of constructing similar power plants in a number of other countries. Thus the tidal source of energy can be considered as a rather particular one, only suitable for utilization in a few geographically suitable areas.

Ocean temperature gradient

One of the sources of the stored solar energy is the temperature gradient in the water of the oceans, from the surface to its depth, caused by absorption of solar energy. In tropical areas this gradient can be as high as 20°C. The utilization of this temperature gradient requires that some liquid be evaporated in a "boiler" (on the ocean's surface), then expanded in a turbine and cooled in a condenser based on the use of deep waters. Various low-boiling liquids, such as ammonia, can be used as the working heat in such a cycle.

The estimates show that if the whole ocean's surface in the tropical and subtropical areas is utilized in this way, the power produced will amount to 70 milliards kW. It is quite clear that this would entail serious ecological consequences. The more acceptable scale will be about 1 milliard kW.

The main technical problems related to the construction and anchoring of such facilities reside in the development of the installations for pumping of large quantities of water as well as transmission of the produced power.

Wave power

The waves of the world ocean contain a considerable amount of energy. The main ideas of the utilization of wave power are associated with the construction of floating platforms based on exploiting the relative displacements to pump water through hydroturbines.

The first large wave-power installation is expected to be built in 1984 in Scotland. The 1 km long chain comprising 50 platforms will be situated at 2.5 km from the shore.

There can be no doubt that studies should be carried out in this area. However, for the time being, it is difficult to imagine what the practical value of this energy source will be.

The above short analysis shows that the renewable energy sources hold large potentialities. But the technologies determining their practical application are at various developmental stages and in most cases they have not yet reached the level of economical viability. For this reason, it is necessary to promote in every possible way the research and development so that these energy sources become actively utilized. As mentioned earlier the problems of power supply will become most acute in the near future in the developing countries, that is why the new technologies must be developed in a way that the particular features of these countries be taken into consideration. U.N. Organisations are called upon to render every help in this respect. An active international cooperation on the problems of power generation will be a guarantee that mankind will successfully cope with these problems.

ELECTRIC POWER IN DEVELOPING COUNTRIES: A BRIEF EXPOSITION OF ITS ROLE IN THE DEVELOPMENT DIALECTIC

KIRK R. SMITH
Energy Program Leader, Resource Systems Institute
East-West Center
Honolulu, Hawaii, U.S.A.

I. Introduction: The Dialectic

In planning and development circles there is much debate about the relative merits of the centralized planning and implementation of projects with their apparent economies of scale as compared with decentralized approaches that promise to more fully involve local human and natural resources. The dialectic between these opposing philosophies, the "top down" and "bottom up" approaches to economic and human development is a long one. Indeed, Prof. Stohr of Vienna has shown that there have been swings in the pendulum between them for two thousand years or more. At some periods one will dominate official thinking and the other will be adopted by counter-establishment or progressive groups and then the pendulum will swing back and the roles will be reversed. He shows that in the last few centuries the oscillation period has become shorter and that, in his estimation, we are now witnessing a swing away from a post-war preoccupation with top-down planning and into a period when bottom-up planning is gradually becoming officially sanctioned. Evidence of this last swing is not hard to find. For example, few institutions are more firmly part of the establishment than the World Bank and, yet, in its 1982 World Development report is the statement:

> "Learning from mistakes includes, above all, reaching a greater understanding of the problems of the poor. This means that programs should be designed and executed so as to encourage the fullest parti-

cipation of local people. Local people best know their own needs and how they can be met. Cost-effective, sustainable programs that reach large numbers succeed by giving full rein to the considerable energies and dynamism of the poor".

The electric power sector perhaps more than any other has been the battleground for this debate in recent years. This is so because of electricity's importance to economic development, an importance not only in substance but also, as critically, in image. The blessings of electrification have been identified as a prerequisite to and, to many observers, as almost a definition of development since at least 1920 when Lenin penned his famous sum (communism = Soviet government plus electricity).

In this brief overview of the recent history of electric power and development, I will not try to present a complete set of statistics of the status and history of electric power systems in developing countries. These statistics are ably provided on a regular basis by the United Nations and its regional economic and social commissions, and the World Bank and the regional development banks, and, in increasingly detailed form, by the national energy and power authorities in many countries (see bibliography). Rather, I want to bring out several cross-cutting issues and will cite the statistics necessary to their explanation. When possible, I will take examples from the Asia-Pacific region where my institute has studied these problems. Throughout, I will try to point to the roles that these issues have played in maintaining the dynamic tension between the two development approaches.

II. Electricity and Economic Growth

There is much evidence for the importance of electricity in the growth of developing-country economies. This evidence is of two kinds, that resulting when growth in the electric power sector leads economic growth and that resulting when it lags.

The Leading Sector

Perhaps the single most important emergent characteristic of the world community of nations, this century is its bifurcation into affluent countries with annual per capita incomes exceeding $ 5000 and electricity consumption exceeding about 2000 kWh/capita and poor countries with incomes below about $ 1500 per capita and per capita electricity consumption less than about 1000 kWh. It is a bimodal distribution with relatively few nations falling in between (1).

It is finding a means to enter into and cross this gap that is the focus of economic development efforts. A few countries are now in the process of doing so. These are called the NICs (newly industrializing countries) or, in the most recent World Development Report (1983), the "upper-middle income" countries such as Malaysia, Brazil, Hong Kong, and Singapore. The role of electricity in the recent rapid economic growth of two such NICs, the Republic of Korea and China (Taipei) (2), illustrates its importance.

During the last two decades, these two countries have experienced higher sustained growth than any other non-oil-exporting country above two million in population. The population grew at a slower rate than the economy, which grew at a slower rate than total energy use, which grew less than electricity consumption. It is a pattern found not only in these two economies but also previously in their culturally similar neighbor, Japan which, after all, was considered a developing country until fairly recently. Indeed, it is possible to place Japan, Korea, and China (Taipei) together on a time line based on their histories of electricity use and economic product. In such a scheme, Korea is seen to lag behind Japan by about 20 years and China (Taipei) by 15.

The second oil shock in 1979 brought basic changes to the electric supply industries in China (Taipei), Japan, and Korea, reducing consumption. In addition to lower electricity demand growth, the unbalanced growth of peak- and base-load demands has become accentuated. As a result of the sharp increase in OPEC oil prices, the Japanese economy has undergone drastic structural changes in industry, shifting away from electricity-intensive materials, thereby causing stagnated growth of base-load. With the second oil shock as a turning point, the comparative advantage

(1) It is instructive to calculate the average income per capita in the world today and identify the countries that most closely correspond to that level. That income is about $2800 (and 1500 kWh/capita) which is in the region between the rich and the poor, where relatively few countries lie. Yugoslavia and Uruguay are the closest, with Argentina and Chile not too much lower. On the high side the next on the list is Venezuela at about $4200.

(2) This awkward term is the one agreed to by both China (Taipei) and China (Beijing) for international comparisons.

of China (Taipei) and Korea in international trade also shifted against electricity-intensive process industries. On the other hand, as the economic living standard greatly improved, the use of air conditioners and refrigerators increased accordingly. Thus, the summer peak has outstripped the winter peak in Japan since 1968, in China (Taipei) since 1972, and in Korea since 1981. Although the trend of greater increase in electricity consumption with respect to GNP growth was substantially dampened by the oil shocks, the share of electricity consumption in total energy consumption has continued to increase. Japan has been undergoing a transition from an oil-based economy to an electricity-based economy, and China (Taipei) and Korea seem to be following suit.

A strong positive relationship between electricity and the economy is also seen in other industrial countries. In a study of 15 OECD countries, the U.S. Electric Power Research Institute found essentially linear relationships of income with electricity consumption in every case, although with differing slopes ([3]). This is in sharp contrast to total energy, which has been shown to be related but not strongly to economic growth. For total energy use, the variations from linearity are striking; for electricity the persistence of linearity is equally striking. There are significant exceptions, however. The states of India, many of which are as populous as good-sized countries, do not exhibit a close correlation of electricity and income, for example.

In East Asia, high growth rates in the economy over the last two decades have led to increases of factors of ten or more in installed electric capacity. The management and financing of such growth rates are difficult. In addition, utilities in China (Taipei) and Korea were able to greatly decrease their system losses over this period bringing them today almost to the level of utilities in Japan and other developed power systems.

One of the principal development uncertainties today is whether other developing countries can follow the path of the NICs such as China (Taipei) and Korea. A number of countries, such as the Philippines and Thailand in southeast Asia, today have many economic characteristics that

([3]) A typical example would be the United States where electricity use has paralleled GNP with at least two changes in slope during this century. The first change in slope from about 0.29 to 0.58 kWh/$GNP occurred between 1910 and 1920. The other to 2.14 kWh/$GNP occurred in 1947. Since about 1974 there may have been another change in slope toward less electricity intensity but there are too few data points yet to be sure. It is clear, however, that total energy intensity during this latter period underwent a substantial decrease.

are similar to those of the NICs before their great spurts of growth. As in the present NICs, the ability to manage the electric power sector will play an important role in this transition for the NICs in the future.

The Impacts of Shortages

In terms of income growth China (Taipei) and Korea have achieved dramatic results in the last twenty years and have generally done so with due regard to income equity. China (Taipei) has also maintained a relatively small ratio of urban to rural incomes. In doing so, the electric power sector has led.

Other developing countries with different starting conditions, including the two largest, have not been so successful. Electricity shortages are a daily fact of life and severely curtail production. In a study of Yucheng County (northeastern China), for example, it was found that on average 50 percent of customers are waiting for power. In this situation it is necessary to develop a set of priorities for which groups of consumers will have first call on the power, or, conversely, who will be cut off first. The following are the dispatch priorities for the utility:

A. Priorities are set to keep as many people working as possible. Priority:
   1. Metal Industries and Railroad
   2. Industry:
      a. Chemical Fertilizer Plant
      b. Cotton Textile Mill
      c. Feed Processing Mill
      d. Wine & Spirit Factory
      e. Minor Industries
      f. Agriculture: Irrigation & Processing

B. Staggered plant shutdowns, off days, three shifts/day.

C. Designated "on day" for each geographical user group (usually a commune).

D. Switching some off and others on in response to complaints.

E. Industry cutbacks during the June irrigation period.

During the June irrigation period, however, industry experiences a considerable power cut and yet it is estimated that only 50 percent of the demand of present irrigation pumps can be met. These pumps only comprise about ten percent of the estimated total demand that would exist if there were reliable power available.

In India as a whole, it is estimated that there has been considerably more than a 10% electricity shortfall in most recent years with much of it being seasonal (low water behind dams). This amount may seem manageable until the pattern of shortfall is examined. Because many demands for electricity occur at the same period during the day, it is often necessary to cut off more than fifty percent of the demand at certain periods. For example, during the irrigation season in some areas, demand can increase more than four times. In India, the dispatch priority is usually highest to urban residents, second to rural consumers, with industry last. In spite of the dispatch priorities, all classes of consumers suffer to some extent, but industry the most. Consequently, there are states in India where electricity shortages experienced by industry approach 50 percent on an annual basis. This has a dramatic effect on output. Indeed, it has been estimated that nearly five percent of GNP has been lost from this cause in some years.

It is important to remember that there are hidden costs to unreliable power other than the obvious shortrun marginal loss of production. There are often significant costs to consumers, who must provide their own diesel backup or otherwise provide against loss of power. In addition, there are opportunity costs because of the loss of long-term marginal production from the failure to develop certain industries that may be appropriate for the area in every way except a need for reliable power. In India there has been a "flight of capital" away from some states, particularly in the east, for this reason. It has been suggested, by contrast, that the development of the so-called "silicon valley" area of northern California was partly due to the existence of extremely reliable power because of the particular confluence of power grids. Semi-conductor manufacture is one of those batch-process industries that is quite vulnerable to power loss.

These shortages in India are severely damaging and due to a range of interacting factors. Part of the problem lies, for example, in the sometimes poor relations among the power, coal, and railway ministries with the result that even existing power plants can often not obtain enough coal. Average load factors are less than 50 percent for many plants. Even when trains do arrive from the mines, they often carry nearly as much rock as coal. Indian coal has a notoriously high ash content in any case, but when contracts are arranged in weight and not energy terms, there can be a tendency to make quotas by filling train cars with even the poorest quality material. India's few nuclear plants also have not had enviable operating records, partly due to past U.S. refusal to supply enriched uranium fuel as originally agreed.

In addition, of course, new capacity has not come on line at the rate needed. This is not so much a failure to predict demand as it is to fulfill the targets set in the five-year plans. In India, for example, hydro projects have averaged 700 percent over cost and 130 percent over schedule. Financing problems also are a problem. When growth is high, capital requirements for construction always tend to exceed revenue, but when substantial portions of customers pay subsidized tariffs and system loss rates exceed 20 percent, the financial squeeze is even greater.

III. Electricity and Investment

There are two important characteristics of power system investment that make its proper management critical for a country's economic well-being: its magnitude and its timescale.

The Largest Capital Output Ratio and Longest Leadtime

Empirical evidence that the power sector seems to lead overall economic development in successful cases and drag down development in other cases, is a strong incentive for planning to spending a considerable fraction of development capital on it. Indeed, this is the case. In India, for example, nearly 20 percent of the total investment in all development projects from 1951 to the present has been allocated to the power sector. Typically, more than 35 percent of state development plans are devoted to power as well. Even at later stages of development the capital requirements of the utility sector are impressive. In 1980, for example, they directly accounted for 13 percent and 17 percent of fixed capital formation in Korea and China (Taipei) respectively. In Korea, utility investments were almost (more than two thirds) as important as total manufacturing investment.

This capital need can add significantly to a country's debt. In the early 1980s, for example, Korea had about 120 MW of nuclear power alone being constructed for every billion dollars of GNP, with China

(Taipei) not far behind. This was about twice the nuclear capital intensity of the next most intensive country, France, and one resulting from a presumption of continued high growth rates not only in electricity use but in the economy.

No other industry has such a large incremental capital output ratio. Put another way, the power industry is capital-intensive and labor-un-intensive compared to other major industries. This has led to its being a target for those concerned for the provision of employment-generating industries. On the one hand, many labor-intensive industries such as textiles require electricity while on the other hand the power industry does not. How these two factors balance in the case of any particular combination is difficult to predict without sophisticated econometric studies requiring data often unavailable or undergoing change.

Another characteristic of power systems is their long investment lags. Major non-nuclear baseload power plants take as much as 6-8 years to bring from conception to completion in most countries although some countries are able to build plants in less than five years. The quickest that nuclear plants can be constructed and readied for use is about five years, while many projects have taken more than ten. Small peaking plants using gas or oil can be built much more quickly, often in less than two years.

The large investment needs of electric power are impressive on a global scale as well. By far most international development funding in energy has been devoted to power projects. In the World Bank, for example, power projects typically have accounted for more than 70 percent of all energy lending. The World Bank has accounted for about 40 percent of all concessional loans in energy, and other multilateral and bilateral agencies have had similar concentrations on power. The future investment needs of developing countries for power development are even more significant. Of about 900 billion 1982 U.S. dollars for energy projects it is estimated to be needed in the low and middle income non-oil-exporting countries by the early 1990s, well more than half will be needed for power projects. This total, it might be pointed out, is about twice the annual income of the poorest half of the world's population.

The Challenge of Optimum Investment

The result of these two characteristics (investments that are large with long lead times) is that good financial management of the power sector is both critical and difficult.

When the growth of the electric power sector reaches 10 and even 20 percent annually as it has in many developing countries, the apparent capital requirements for plants needing to be planned now can be dramatic. At a 15 percent annual growth rate, for example, the installed capacity increases by a factor of four in ten years. This also means that relatively slight changes in demand forecasts can have big effects on the need to plan new capacity. If the true growth rate turned out to be 11.6 rather than 15 percent, for example, the need for capital would be decreased by the amount necessary to purchase a system as large as the one existing today (a factor of three rather than four increase in ten years).

This should provide incentives to planners and decision makers in developing countries to examine electricity forecasts carefully. In many cases it may be that a combination of incentives, regulations, and taxes designed to increase efficiency and avoid large system peaks could avoid the need for expensive new facilities and increase the capital efficiency of the power system. In these circumstances, relatively small improvements in the power sector might free significant amounts of capital for use in other sectors and thus increase the overall economic growth rate of the economy.

In many cases, countries have been so worried about providing enough capacity during periods of rapid growth that they have paid too little attention to load management. For example, in India in 1982 the average load factor was less than 50 percent. Some observers have noted that these problems have resulted from too much influence by strictly engineering considerations and not enough economic and financial planning. Consequently, peak loads have sometimes become unnecessarily large. Poor countries tend to have peak loads dominated by irrigation while OECD countries mostly have winter heating and summer air conditioning peaks. Early in their growth spurts NICs have peaks dominated by industry but, later, residential loads begin to dominate as incomes rise. In China (Taipei) and Korea, for example, as income rose the summer air-conditioning peak began to dominate just as the growth in electricity-intense industry began to slow.

As a result of this neglect, increased attention to load management will likely reap large rewards in many if not most developing countries, being cheaper than additional capacity at the margin. In addition, advanced technologies for sophisticated load management of both large industrial as well as small residential and commercial consumers are now becoming available. These techniques involve use of radio, power-line ripple, or phone communication and cheap reliable microelectronics to greatly increase the rate of interaction between utility and consumer, and therefore, the potential for load leveling.

In addition to low load factors, most developing country power systems have large loss rates, in some cases reaching close to 50 percent. A significant portion of this loss in many areas is due to pilferage and thus might be thought to serve, at least temporarily, some social benefit. Often, however, it is not the very poor who benefit by this pilferage. Over the long term, of course, such losses need to be controlled. The advantage of such control can be large. A system starting with losses of 40 percent and cutting them to 20, for example, can save itself roughly two years of capacity needs, even if growing at the relatively rapid rate of 10 percent. Studies have often shown that there is a higher marginal return on investment in loss control than in new capacity for such systems.

In a similar way to the potential for loss and load management, developing country economies are often the fertile ground for the introduction of some of the attractive electricity-saving efficiency measures now being developed across the world in response to higher energy prices. It is surprising how inefficiently electricity is used in some developing countries. It is hard to dispel the notion, however, that since they use relatively little in total, developing countries need not concern themselves with increasing efficiency. Just the opposite is true, of course, particularly when growth in demand is as rapid as it is in so many developing countries. The risk of relying on efficiency alone is, of course, that the power system will be inadequate to the demand and that significant costs of shortages and unreliability will be incurred.

Choosing the optimum path between too little and too much investment in the power sector is not easy. Indeed, the world can be roughly divided into two groups today based on which kind of failure has occurred. Most industrial countries are now experiencing a surplus of capacity, in some cases in embarrassing amounts. This has resulted from the tendency to extend the rapid growth rates in the 1960s and early 1970s into the future and to plan expansion accordingly. Most developing countries have experienced the opposite problem, partly because of forecasting problems, but mainly through inability to quickly arrange system planning, financing and management, and construction. It is instructive to note, however, that the problem of deficit can quickly turn into one of surplus. Both Korea and China (Taipei) for example, have significant excess capacities today and wish that they had paid more attention to load management in previous years. They are belatedly delaying some large baseload plants and increasingly relying on smaller plants with shorter lead times, as well as concentrating more on load management.

IV. Electricity as the Leader in the Post-Oil Transition

To a first approximation, the energy problem is the oil problem. The central objective of the energy policy of nearly every country is to reduce oil imports or, if an exporter, to reduce domestic consumption so that exports can be sustained. The electric power industry is often the most important agent of change in these efforts.

The Most Homogeneous and Consolidated of Energy Sectors

Changing patterns of direct fuel use among residential, commercial, agricultural, and industrial customers is not easy to accomplish in short time periods. The number and variety of users are large and application of any particular policy tool such as pricing or subsidies often has uneven effects on different consumers that can create political difficulties. The power sector on the other hand is normally consolidated under one or a small number of utilities directly or indirectly controlled by the government. Even when there is more than one, they are not in direct competition and there are enough similarities among their interests to consider them homogenous.

Although the electric power sector is not a final user of energy in a physical sense, it does account for a large fraction of primary energy needs. Typically, 35-40 percent of commercial fuels are used by the power sector in developed countries. Although this might be only 10-15 percent in some developing countries, the growth in demand will greatly favor electric power, as mentioned above. Consequently, there is often substantial opportunity for partly shifting a nation's pattern of overall demand away from oil by concentrating on the power sector.

This potential is an illustration of the difference between the controlability of energy used by the consumer versus that used in intermediate production. The energy use in intermediate production is typically decided upon primarily by economic considerations. There is relatively little attention to any custom, cleanliness, or convenience factors that are not reflected in the price of use. At the final consumption stage, "at the level life is lived" in Richard Heilbroner's words, however, such considerations can dominate. Consequently, it is more difficult to effect changes in the final consumption sector through such mechanisms as pricing. Which energy form is used to create the products and services during intermediate production is of little interest to the final consumer. Few people will care, for example, whether a bicycle they buy is made with coal or charcoal while they may well care whether their household stove is fuelled by coal, wood, or gas. In a similiar way, the electricity from coal is the same as that from oil and thus it is not necessary to expect changes in energy use at the consumer end when shifting fuel sources within the power sector.

Examples of Successful Post-Oil Transitions

Energy planners in developing countries are caught between two conflicting demands: to provide for rapid growth in energy needs and at the same time reduce dependence on imported oil which traditionally has been the easiest source to expand. For this reason it is useful to examine cases in which both these goals have been addressed with some success through restructuring the power sector.

Korea and China (Taipei) had incomes and other economic characteristics in the 1950s that are typical of many other developing countries today. In the intervening period they not only experienced significant economic growth but they have succeeded in reducing the trend toward greater oil dependence. In China (Taipei), the peak in oil dependence occurred a few years after the first oil crisis, and fell more than 10 percentage points overall and by about 25 in the power sector as new non-oil power plants came on line. In Korea oil dependence reached its highest level in 1979 and has since declined, mostly through the changes in primary fuel requirements of the power sector. In both economies, the ability of other energy consuming sectors to shift away from oil has been much less impressive. Although part of this success has occurred through the choice to develop nuclear power, which may not be appropriate for many other developing countries, it is significant that coal and LNG have also played key roles along with important improvements in thermal efficiency and reduction in line losses.

V. Leading Actor in the Evolution of the Downstream Petroleum Market

The ability of the electric power sector to assist in the shift away from oil comes with side-effects that interact directly with changes from other causes that are now reshaping the global petroleum market. The result is some uncertainty about the wisdom of moving away from oil at too fast a rate.

Most Substitutes for Petroleum are in Power Generation

Oil is not used in its natural state but in the form of refined products, the mix of which depends on the relative prices and demand of different products, the availability and price of various crude oils, and cost and flexibility of different refinery configurations. It is only a restatement of the previous section to say that most of the successful substitutes for oil have been in power generation, which mainly uses relatively heavier grade products, residual fuel oils. Coal, nuclear, and gas have been the major substitutes and all, except in countries with gas distribution pipeworks, have been principally used to generate power. Even the most promising of the alternative energy sources, wind, geothermal, biomass, and solar thermal have the largest total potential in power generation. The only new "source" of energy that has shown substantial savings of products in the light and middle grades has been conservation, (increased efficiency), particularly in the transport sector.

As countries all over the world succeed in employing substitutes for oil, the result is a shift in relative demand away from residual oils toward lighter products on world markets. Since the greatest growth in energy demand is occurring in developing countries, there is a concommitant increase in demand for the middle grades (middle distillates such as kerosene and diesel). These are the fuels of development, often the first modern (or "commercial") fuels to be used as a society moves away from the traditional biomass fuels. In relative terms, the demand for lighter products such as gasoline is remaining relatively stable.

Compared to 1972, for example, it has been recently estimated by the World Bank that the demand for middle distillates will have grown from 30 to 47 percent of total oil demand in LDCs by 1995. Heavy grades will drop from 38 to 21 percent, including an absolute annual decline of nearly 1 percent after 1980. Light distillates are thought to increase from 15 to 18 percent over this period. These shifts are expected to be more dramatic in the relatively fast-growing economies of Asia than they will be in, for example, the poor countries of Africa. The OECD countries will also experience a relative and, possibly, an absolute decrease in demand for heavy products along with modest increases in both light and middle distillates (the latter due to diesel and jet fuel).

In conjunction with these changes in the pattern of global demand for petroleum products, a significant change is also taking place in global refining patterns. The 1970s were a time when the producer countries wrested control over production and crude oil pricing (the upstream market) from the large oil companies. The 1980s, however, appear to be characterized by a movement to gain more control over downstream operations as well (refining, transport, and product sales). This can be seen in the expansion of OPEC refining capacity that is being constructed in the Persian Gulf and elsewhere. This expansion is occurring in a time of great global surplus in refining and when hundreds of refineries have closed in Europe, Japan, North America, the Caribbean, and Singapore, the traditional refining centers.

The Economics of Residual Fuel Oils are Changing

The changes in the downstream market have several important implications for oil-importing developing countries some of which relate directly to the power sector. Among these is a need for means to control and predict the growth in demand not only for petroleum in total but also for each of the major products separately.

The shift away from the heavier products presents a country with several options. It can still depend on its own refineries, which in most LDCs are likely to be simple and fairly inflexible facilities unable to quickly shift their production to the middle and lighter ends of the product slate. In this case, there may not be any actual decrease in import requirements for crude oil, only an increase in the amount of fuel oil needing export markets. Indeed, depending on the growth in demand for other products, a continued reliance on indigenous refineries can actually lead to growth in crude demand in spite of an overall decrease in demand for oil. This option is not attractive for these reasons although it requires no immediate capital expenditures.

Another option is to add to existing refining capacity the capability to crack crude oil into a mix of products more oriented to the middle and light distillates. A variant of this option is to buy or lease excess foreign capacity, probably in the entrepot refining centers of Singapore or the Caribbean. Either way, this option is expensive and brings some risk because of the low refinery capacity factors accompanying global fluctuations in the oil market. In times of oil surplus there is excess capacity and in times of oil deficit there is lower access to a variety of crude oils. Products, therefore, may be available cheaper from older (already amortized) refineries or those new OPEC refineries with relatively low operating costs, government-subsidized capital, and assured supplies of crude. A vulnerability index of regions, designed to reveal the relative sensitivity to world market fluctuations, shows that other than China (Beijing), which is basically insulated from direct impact, most of the developing regions of the world have a vulnerablity midway between the highly vulnerable refining centers of Western Europe, Japan, and Singapore and the relatively safe centers in North America and Eastern Europe.

A third approach is to increase the imports of petroleum products from the traditional and newly emerging product-exporting refining centers. This is risky because it makes a country even more vulnerable to changes in the demand pattern for products worldwide as well as to the specific characteristics of refineries built elsewhere by others.

The last option is to implement measures designed to even out the demand pattern across the major grades of products in order to match the pattern to existing refineries or a more slocoly evolving mix of refineries. It may well be, for example, that it would be in a country's best long-term interest *not* to move rapidly away from oil dependence if doing so creates a substantial skewing of the product slate.

As a result of the changing downstream market, power capacity planners and dispatchers in national power utilities today are faced with choices related directly to estimates of the absolute prices of crude and fuel oils and their ratio. The real price of residual oil has been dropping and the crude: reside ratio has been rising as the surplus in residual fuels increases. Financial analyses in a number of Asian countries have recently shown, for example, that it is often cheaper to retain *old* oil-fired plants rather than build new coal-fired plants relying on imports or other long-distance transport of coal. This is a fairly new development in relative prices. If the crude: reside ratio rises much further, in addition, it may well be best from a financial viewpoint to build *new* oil-fired capacity. This may be true even when a country has no significant problems caused by the skewing of product demand slates.

From this quick overview, it can be seen how important to national energy planning are accurate estimates of not only total future oil demand but also the demand within each of the major product groups. In addition, it can be seen how valuable it could become to be able to control the product demand slate so as to reduce skewness. Again, it is the power sector that offers planners the most easily accessible lever to accomplish such manipulations.

VI. The Dilemma of Scale

Nowhere is the battle between top-down and bottom-up planning more distinct than in the power sector and nowhere in the power sector is it so vigorous as in the debate over the proper scale of development. To what extent should power system expansion rely on the extension of central grids connected to relatively large power plants versus decentralized community-sized systems? This is a question confronting planners in many developing countries.

The answer is not simple and unchanging for there are many countervailing factors, many economies as well as diseconomies to both small- and large-scale facilities.

The Bright and Dark Sides of "Small is Beautiful"

One manifestation of the swing of Prof. Stohr's pendulum toward more sympathy for bottom-up planning has been the relatively recent popularity of the intermediate technology and "small is beautiful" movements, which have emphasized the benefits of scaling technologies according to a broader set of values than just those represented by traditional financial analysis. In particular, they have emphasized the importance of local self-reliance, use of local human and material resources, and the potential decreases in vulnerability to widespread societal disruption that can come with decentralization.

Another important advantage claimed for small-scale and locally controlled technologies is protection for local cultures from directly competing within and thus becoming part of the global socio-economic Weltanschauung.

In addition, it is argued, decentralized systems can better reflect local values and customs. They are also more flexible in that they can more quickly accommodate changes in values.

Such arguments hinge on a distrust of specialization, both in economic and political affairs. Traditionally, economic specialization has accompanied economic development. Energy production, for example, was once the task of every family but in the developed economies is now the role of specialized workers. To keep technologies small, close at hand, and labor-intensive is to keep specialists to a minimum.

An implied distrust of political specialization is also part of such movements as it is among most bottom-up approaches. There is a worry that the means of local control over centralized political institutions may be inadequate to the task of representing local values in decision-making.

There are also advantages to central decision makers of decentralized systems. In making decisions about allocation of resources to a power plant or most other projects, decision makers must make judgments not only about the efficiency (economic viability) of the project but also about its impacts on equity (who wins and who loses). Among the advantages of small-scale technologies is that, relative to large-scale systems, it is often easier to apply both the efficiency and equity criteria.

The equity criterion is easier to apply because small-scale systems tend to distribute their benefits and deficits to the same group of people. The workers who gain employment, the customers for the electricity, and the neighbors who experience the environmental hazards are likely to be more congruent, for example, with a small local biomass-powered steam plant than with a large central coal plant.

Importantly, however, small-scale technologies also less require that less faith be placed in the always difficult, often arbitrary, and frustratingly controversial means of evaluating non-economic costs and benefits now available to decision makers. This is so because a larger part of the evaluation can be done within the heads of the people who will have to live with the decisions. Instead of relying on outside frameworks for evaluation, in which costs and benefits of entirely different sorts must be combined and weighed against one another, the internal calculus of the individual can be tapped. Those who gain the benefits of the technology are also those who will be subject to its disbenefits. It is up to them to decide which side prevails and they can do so by using their own experience and with minimal use of external decision tools. This advantage to small-scale systems is an example of what is sometimes called tbe Holdren Principle, after John Holdren of the University of California, who first articulated it.

There are also disadvantages to small-scale systems. Important among them are the apparent economies of scale in construction. History has shown a general, although by no means universal, tendency of decreasing cost per unit for electric power generation, at least up to several hundred megawatts in systems serving fairly densely populated areas. Transmission and distribution costs and losses can result in the opposite conclusion for areas of low population or load density.

It is important to remember that there are also economies of scale in design and management of systems that come in a few large units rather than in thousands of small units fitted to local conditions. Many feel that it is these human resources that are in shortest supply in LDCs and, thus, should be allocated carefully.

Small systems can also be subject to the Tragedy of the Commons, in which the decisions of individuals acting in faith with their individual values can be destructive to the community as a whole. An example might be the multiple damming of a stream for small-scale hydroelectric power plants where no one dam could be shown to reduce water flow beyond some critical point, but, in concert, the critical point was reached.

There can also be important environmental health advantages to large scale. When health insults are produced at a fuel cycle stage that is composed of many small facilities, there is a possibility that the negative results per unit of pollutant released will be higher than those from a centralized system. In other words, per ton released, the pollutants from a decentralized power plant can in some cases cause more damage than a ton from a central power plant. This is a function of the effectiveness of the pollutants reaching people. Of course, for some types of pollution, such as carbon dioxide, the location of release is not critical. In other types such as certain types of water pollution, there may be threshold effects that result in less impact per unit material released from small-scale systems.

This effect can be seen in a comparison of the most common combustion device in the world, the household biomass-fueled stove, with an infamous polluter, the coal-fired power plant. A study by the Brookhaven National Lab has calculated the air pollution exposure commitment of a typical U.S. coal-fired power plant. Modification of these calculations for Indian conditions indicates that approximately 1000 EU (Exposure Unit = μg-person-year/m^3) per ton of particulates could be expected. In contrast, measurements by myself and Indian colleagues in Indian villages have shown that a ton of particulates from typical biomass-powered stoves causes at least 200 times as much exposure. Relative concentrations are equally high. Women cooks typically experience hundreds of times the concentrations that would be deemed acceptable by the relevant air pollution standards.

This should cause little surprise since few activities are more evenly distributed than domestic cooking, which is done in every household every day. The relative effectiveness of pollutants in reaching people is thus high compared to centralized facilities.

This comparison is not meant to imply that electric cooking is better than traditional biomass-fired cookstoves. There are many other considerations and probably better options than either. It does indicate, however, that the worst pollution may not always come from the largest and most obvious facilities and that pollution control efforts, consequently, should consider small-scale systems when calculating where the greatest marginal reduction in exposures is to be achieved per rupee spent.

The Broader Implications of Scale: A Case Study

The small island nations of the South Pacific have acutely felt the changes in the world oil market in the last ten years. They are in the position of not only having limited indigenous energy production beyond traditional biomass fuels and some hydroelectric power but also of importing all their petroleum needs in the form of products. They have traditionally been price takers in the product market because of the limited number of active competitors selling in the relatively small regional market. In addition, the products must be transshipped from port cities to outer islands within each major group, often in small volumes at great cost.

As is true in many developing countries, rural electrification is a major objective of many of the Pacific Island governments. While extension of central grids can be considered in some areas of the main islands, there are dozens of other islands as well as many remote areas on the main islands where a centralized grid is clearly impractical at present. Consequently, there has been a history of electrification by diesel sets, often with the result that electrification costs have been extremely high and well beyond the revenue that can be collected by the power authorities. This can lead to deteriorating maintenance and poor service, making revenue collection even more difficult.

The last set of oil-price rises and the advances in renewable energy technologies seem now to have opened up a range of other electric power possibilities that, depending on decisions made about scale, can be economical when compared with diesel. In some particularly remote and small islands with significant coconut production, for example, where the costs of importing diesel fuel and exporting copra are high, it can be cheaper with present-day technology to substitute coconut oil for diesel fuel in local applications. This conclusion depends, of course, on the global market for the two liquids as well as on the local logistics.

The more general situation is illustrated by Figure 1. It shows that there is a region of remoteness (as represented by local diesel fuel cost) and scale (as represented by the size of the service area in kW) where a range of local renewable energy options seems to be economically viable for electricity generation. Not shown in this phase diagram are wind and hydropower. These are site specific and good sites can make them

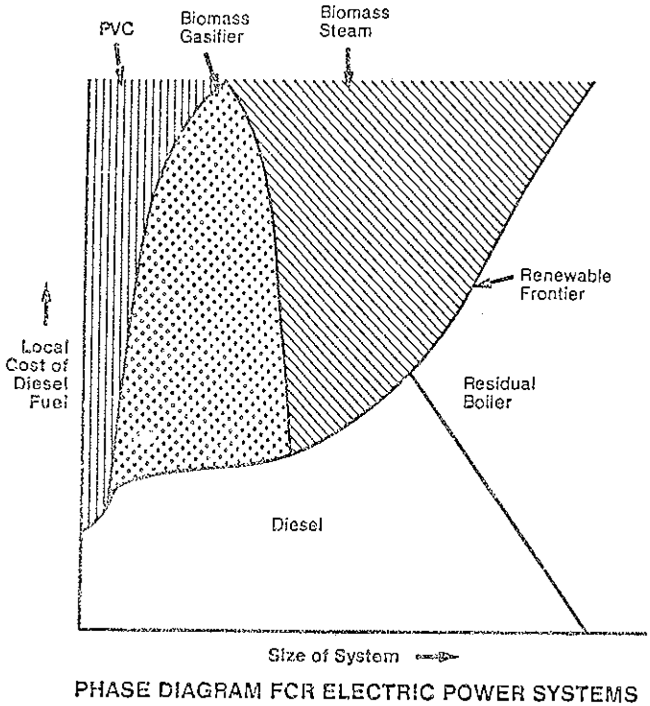


FIG. 1. In the islands of the South Pacific, a number of alternatives to diesel electric power are economical, depending on the remoteness from supply centers (here represented by the local cost of diesel fuel) and the project scale. With appropriate site conditions, of course, hydro or wind power can be economical as well.

PVC = photovoltaic cells.

economical essentially anywhere in the region. The biomass and photovoltaic (PVC) options are also site specific, but the necessary environmental conditions exist rather widely. This diagram is qualitative only and does not show actual figures for cost and scale. It seems, however, that the triple point between diesel, biomass gasification, and biomass steam is at about 800 kW and $ 0.60/liter. Passing through this point is a dividing line that is labeled on the figure as the "Renewable Frontier". Above this line, renewable sources seem to be more economical.

For small, roughly household, scale provision of simple needs such as lighting and communication, PVC with batteries is an attractive option. It certainly beats kerosene lamps and, in many places, diesel and gasoline powered generators. The scale dilemma, however, is not so much in deciding what is economical today under static conditions, but deciding what is optimum given the likely and desirable future development path. If the need for electricity is to remain small, PVC may be the best choice because it can be used at relatively high capacity factors for premium uses. Should a village begin to develop quickly, however, the need for additional electricity may quickly exceed the capability of small PVC sets to provide not only economical electricity but also to adequately meet peak load and power quality requirements. Thus, in spite of an expected low capacity factor at the beginning, it may be best to invest in some sort of larger system to accommodate expected future growth in demand for the important but less than premium uses to come.

It can easily be seen that such a choice involves more than economic planning. It also involves societal and individual value judgments about the appropriate speed and direction of development.

In the particular case described here, there is a partial technical fix available that helps avoid making a decision today that tomorrow may seem to have been imprudent because it locked a community into a particular development path. PVC/battery sets are available now that can be installed and removed fairly easily. Thus, it is possible to consider that the installation will be temporary only until a larger grid capacity is available, for example by extension of a central grid into the village. At that time, the PVC sets could be packed up and taken to a village even further away if appropriate financial and management arrangements have been made in advance.

VII. Rural Electrification

Most of the world's energy is used in the cities of urbanized nations but most of the world's people live in the rural areas of the developing world. Thus, in terms of the number of people who rely on them, the most important fuels in the world today are the same as they have been since the discovery of fire, the traditional biomass fuels. Some important characteristics of these fuels are that in their natural forms, they are difficult to store, transport, and use because they are of low energy density, poor uniformity, and, in direct combustion, dirty. The principal manifestation of these deficits is that the traditional biomass fuels can be relied upon only for survival and not for development. The survival energy needs are for cooking, space heating, and, in some areas, draft animal power.

Development, however, will require a range of higher quality fuels (solid, liquid, and gaseous) as well as electricity. These energy forms are needed for the concentrated and portable applications of energy accompanying rural development, both in agriculture and industry. While it may be that biomass can help provide the energy sources for the production of these high-quality energy forms, it will be biomass harvested and utilized in ways entirely different from those employed traditionally. Sustainable managed production, for example, will have to supplant unmanaged gathering as the means of production if biomass resources are not to be exhausted. So different are these new ways of producing and using biomass that they could well be distinguished as "modern" as opposed to "traditional". The energy changes in rural areas can thus be characterized as the Post-Traditional-Biomass Energy Transition.

Rural people in countries that developed in the decades before the major oil price rises turned to the petroleum middle distillates (diesel and kerosene) as high-quality substitutes for biomass fuels as well as for energy sources to meet their development energy needs such as tractor power. Because oil was cheap and required relatively little infrastructure to be used, development efforts concentrated on the provision of the other principal energy form, electricity.

A Re-Evaluation

Rural electrification expenditures were and still are a large part of the development budgets of developing nations as well as international banks and donor agencies. Since the mid-1970's, however, there has been increasing criticism and cynicism related to many of these efforts. In part, this is due to the changing world energy situation. No longer is it safe to assume that rural energification will take care of itself through the spread of cheap middle distillates, thus freeing outside development efforts to concentrate on electrification. In a world in which no energy form is cheap, high-quality, and abundant, there is need to look carefully at the relative allocation of scarce development resources to provide fuels versus providing electricity.

Another reason for re-evaluation of rural electrification lies in the expectation by some that electrification would be a way to stem the tide of rural-urban migration. If some of the benefits of life in the city, such as lights, radio, and television, could be provided in rural areas, the argument goes, the pull of the city would be less. In reality there is little evidence of this effect. Indeed, the countries with the most complete rural electrification schemes are those with the highest urban migration rates. It thus could be argued that exposure to outside influences and the agricultural unemployment from increased productivity that can accompany electrification could actually be factors favoring urban migration.

A third factor leading to a re-assessment is the swing in official development circles toward more concern with bottom-up planning. Rural electrification in its traditional form concentrated on the extension of central grids. This leads to the potential for loss of local control and initiative through dependency on remote and centralized institutions.

The result of these factors has been a definite shift in research and policy discussions toward an examination of energy for rural development in a broader context. In most countries, however, it has not yet led to a significant diminishing of efforts dedicated to rural electrification. Partly this must be attributed to the disappointing prospect so far provided by the wide range of indigenous alternative options for energy production that have been investigated, a situation, however, showing signs of improvement. Partly, this potential for improvement lies in matching planning, management, and labor resources at the local level with ideas and technologies from outside.

In addition, the history of rural electrification is not without significant successes, at least by most measures. The rural electricity cooperative movement in the Philippines, for example, has apparently been able to meet the needs of a wide range of rural people, including many of the poorest. According to studies done in the early 1980s, economic productivity and a series of social welfare indicators improved in electrified areas. The cooperative approach also provides evidence for the viability of a (semi) bottom-up approach.

Such successes are encouraging and clearly show the benefits that can accompany electrification in an appropriate setting. The fact remains, however, that electricity is nearly useless as a means to directly alleviate the growing shortages of energy for survival. Essentially nowhere in the poor half of the rural world will electrical cooking and heating be viable in the next half century [4]. Consequently, rural electrification should not be confused with or seen to be a substitute for immediate needs for programs designed to augment supplies for meeting minimum energy needs.

The Vitamin Analogy

The role of electricity in the early stages of rural economic development might be likened to the role of vitamins in nutrition — vital but not needed in large amounts. The real basic needs for survival, the carbohydrates, are the biomass or other fuels for heat generation mostly in cooking and space heating. These are needed in large amounts and continuously or severe repercussions result. The real fuels of development, analogous to the body-building proteins, have in the past been the liquid petroleum middle distillates. A principal, and as yet unanswered, dilemma of rural development is choosing which fuels will provide the "protein" for development in the future.

Just as it is not appropriate or possible to spend hundreds of dollars per kilogram for carbohydrates, it is not possible to do so for the basic fuels of survival. For protein (or liquid fuels) it is possible to pay a bit more per kilogram (or megajoule). For vitamins it is possible to pay at the rate of hundreds of dollars per kilogram and, the analogy would argue, it can be appropriate to spend relatively large amounts per unit of energy for small amounts of electricity. In other terminology, the marginal benefit of the first bit of electricity is high.

This implies that a basic part of rural energy development should be the supply of these electric "vitamins" but not necessarily to attempt to supply large amounts, at least initially. These vitamin-like needs are lighting, communications, and, perhaps, community or neighborhood

(4) Examples of exceptions to this generalization are the plans in parts of China (Beijing) to use off-peak power for space heating in rural areas.

refrigeration for medical supplies. This should be done even if the costs are high per kWh. Overall, however, most of the total energy supplied might best be in the form of solid fuels for heat generation and liquid fuels for motive power (the carbohydrates and protein). As development proceeds, a relatively balanced demand from irrigation and small industry as well as residences can be encouraged and thus, economically met through further electrification.

VIII. Electricity's Future Role

There are a number of important issues directly related to the role of electricity in development that I have not addressed. Included are the central importance but practical and political difficulties attending proper pricing policies; the uncertain future of sophisticated and unforgiving technologies such as nuclear power; the large capacity and potential environmental and political difficulties associated with various ambitious international hydropower schemes on several continents; and the emerging possibilities of modifying reliability requirements to allow for a more economical and substantially different mix of central and local generation.

The basic unresolved question about electricity in development is whether the presently developing countries will necessarily follow the same or similar paths as have the NICs and developed countries of today. There is much weight of history behind this path but much new technology and many new approaches to planning that now can be wielded by countries with this history as a lesson.

To end on a more philosophical note, I will first illustrate briefly how little we know in some ways about the ways electricity interacts with society and then speculate on its role from one sort of long-term and global standpoint.

An Indexing Dilemma: The Norway Paradox

To study and make decisions about electricity in relation to other forms of eneregy it is necessary to have a standard and consistent means of comparing the two. An index is required that allows researchers, planners, and decision makers to gain a clear and undistorted view of the relative values of different energy forms including electricity.

So much seems obvious and uninteresting until the present indexing conventions are examined. Severe difficulties soon appear. Take, for example, a simple comparison of the total energy efficiency of one European country with the average for all OECD countries. In 1979, according to World Bank statistics, Norway had an overall efficiency of $ 0.89 compared to $ 1.19 per kg coal equivalent for all OECD countries. This makes Norway look rather like an energy spendthrift by comparison. The other major source of energy statistics in the world, the United Nations, however, tells a quite different story. It shows that Norway is actually more efficient at $ 1.67 compared to OECD at $ 1.44 per kg of coal equivalent. How can this be?

The discrepancy, of course, is due to the way the two organizations index what is called "primary electricity", hydropower in this case. This example in some ways is trivial but in other ways profound. It illustrates that electricity cannot be compared directly to fossil fuels without making indexing assumptions that restrict the universality of the result. Indeed, this problem taken more broadly calls into question the entire practice of energy accounting across fuels.

In the past it was basically hydropower along with a bit of nuclear power that led to this particular type of discrepancy. Only minor problems are created by indexing fossil fuels which have comprised the bulk of "commercial" energy use. As policy extends to the "non-commercial" fuels and as the many alternative electricity sources come into more prominence the indexing problem is exacerbated because few, if any, can be unambiguously indexed against fossil fuels.

At one level this is an academic issue, but in a world where policy choices involving billions of dollars hinge on relatively small differences in energy tabulations, the potential damage from distortion is high. At a more abstract level it illustrates how poorly society has integrated the growing age of electricity into its thinking.

Predicting the Future with the H/C and e/n Ratios

Cesare Marchetti of the International Institute for Applied Systems Analysis has pointed out that the average hydrogen to carbon ratio of all the fuels used in the world is slowly increasing. The ratio is about 0.1 for pure wood, 1 for coal, 2 for oil, and 4 for gas. According to his trend analysis using a logistics curve, the ratio of 4 would be reached early next century. This would not imply that only gas would be used but that hydrogen itself would have become a major secondary energy carrier, balancing the remaining uses of other fuels with lower H/C ratios. The eventual limit, of course, would be an all-hydrogen energy economy.

An alternative analysis of these same data, however, reveals a different end point. If instead of H/C, one takes the ratio of electrons to nucleons in the average fuel, a similar trend line is seen. In this case, however, it is possible to account for the growing role of electricity at end use. The eventual limit becomes, then, not an all-hydrogen economy with an e/n ratio of 1 but one that is all electric.

Interesting speculation but, of course, the energy needs of greatest immediate importance are those that if ignored will have potentially grave impacts for large numbers of people: reduction in the potential for international conflict inherent in some kinds of energy trade; prevention and alleviation of the threat to long-term sustainability of ecosystem services from both small- and large-scale energy technologies: and reduction of the poverty of that half of humanity living in increasingly precarious conditions mostly in the rural areas of developing countries. All three of these issues are only likely to be solved through both concerted top-down efforts and the operation of value changes from the bottom up.

REFERENCES

Asian Development Bank, *Asian Energy Problems; An Asian Development Bank Survey.* Praeger Publishers, New York, 363 pp. (1982).

Asian Development Bank, *Asian Electric Power Utilities Data Book.* ADB, Manila, 222 pp. (1983).

Asian Development Bank, *Regional Rural Electricity Survey.* ADB, Manila, (1984).

BARANSKI D., *Electricity load management in Yucheng County.* Agricultural Engineering Department, School of Tropical Agriculture, University of Hawaii, Manoa (1984).

COLOMBO U., *Alternative energy futures: the case for electricity.* « Science », *217*, 705-709 (1982).

East-West Resource Systems Institute, *Proceedings of the RSI Conference, Nuclear Electric Power in the Asia-Pacific Region,* January 1983. « Energy International » (in press) (1984).

East-West Resource Systems Institute, *Electric Power: Proceedings of the sixth annual meeting of the Asia-Pacific Energy Studies Consultative Group,* May 1983. « Energy International » (forthcoming).

East-West Resource Systems Institute, *Papers of the ASEAN Electric Futures Conference,* Jakarta, April (1984).

Economic and Social Commission for Asia and the Pacific, *Optimization of the Utilization of Electricity Generating Plants.* Energy Resources Development Series No. 23, ESCAP, Bangkok, 91 pp. (1981).

FESHARAKI F., BROWN H., SIDDAYAO C.M., SIDDIQI T., SMITH K.R. and WOODARD K., *Critical Energy Issues in Asia and the Pacific: The Next Twenty Years.* Westview Press, Boulder, CO (1982).

FESHARAKI F., ISAAK D.T., KIM H.T. and KIM Y.H., *Oil Import Strategy and Refinery Rationalization Policies in Korea.* Draft discussion paper, East-West Resource Systems Institute, Honolulu, 177 pp. (1984).

FESHARAKI F. and ISAAK D., *OPEC and the World Refining Crisis.* Special Report No. 168, The Economist Intelligence Unit Ltd., London, 129 pp. (1984).

HAFELE W. and others, *Energy in a Finite World.* Ballinger Publishing Co., Cambridge, MA (1981).

ISLAM M.N., MORSE R. and SOESASTRO M.H. (eds.), *Rural Energy to Meet Development Needs: Asian Village Approaches.* Westview Press, Boulder, CO (Forthcoming) (1984).

JACOBS J., *Why TVA failed.* « New York Review of Books », *31* (8), 41-47 (1984).

KIM Y.H., *Major Issues and Their Policy Implications in the Development of Electric Power Systems: Cases of China (Taipei), Japan, and Korea.* Working Paper WP-83-21, East-West Resource Systems Institute, Honolulu, 106 pp. (1983).

KIM Y.H. and SMITH K.R., *Electric power in economic development: the northeast Asian experience.* Presented at the Conference of the International Association of Energy Economists, New Delhi, 4-6 January, 33 pp. (1984).

LOVINS A.B. and LOVINS L.H., *Prepared testimony on long-term demand for electricity.* Given before the Subcommittee on Energy Conservation and Power, Committee on Energy and Commerce, U.S. House of Representatives, Washington, D.C. (1983).

MUNASINGHE M., *The Economics of Power System Reliability and Planning; Theory and Case Study.* The Johns Hopkins University Press (for World Bank), Baltimore, 323 pp. (1979).

MUNASINGHE M., *Optimal electricity supply; reliabiltiy, pricing and system planning.* « Energy Economics », *3* (3), 140-152 (1981).

MUNASINGHE M. and WARFORD J., *Electricity Pricing.* The Johns Hopkins University Press, Baltimore (1982).

MUNASINGHE M. and SCHRAMM G., *Energy Economics, Demand Management and Conservation Policy.* Van Nostrand Reinhold Company, New York, 464 pp. (1983).

National Rural Electric Cooperative Association, *Report on the Philippine Rural Electrification Impact Survey (1981).* International Programs Division, NRECA, Washington, D.C., 42 pp. + appendices (1982).

PACHAURI R.K., *Electric power and economic development; the case of India.* « Energy Policy », *10* (3), 189-202 (1982).

Pacific Islands Energy Studies Project, *Pacific Islands Regional Energy Report.* East-West Resource Systems Institute, Honolulu (1983).

Resources for the Future, Inc., *Rural Electrification Studies of the ARDEN Project.* RFF, Washington, D.C. (1981-83).

SANGHVI A.P., *Economic costs of electricity supply interruptions; U.S. and foreign experience.* « Energy Economics », *4* (3), 180-198 (1982).

SEARL M.F., *The relationship of electricity to aggregate economic activity in industrial economies — some empirical observations.* Presented at the Fifth Annual Meeting of the International Association of Energy Economists, New Delhi, 4-6 January, 22 pp. (1984).

SMITH K.R. and BROWN H., *From Pakistan to Japan: the energy problems of Asia.* « OPEC Review », *4* (3), 19-54 (1980).

SMITH K.R., AGGARWAL A.L. and DAVE R.M., *Air pollution and rural biomass fuels in developing countries: a pilot village study in India and implications for research and policy.* « Atmospheric Environment », *17* (11), 2343-2362 (1983).

SMITH K.R. and *others, Biomass Fuels, Air Pollution, and Health.* World Health Organization (forthcoming) (1984).

STOHR W.B. and TAYLOR D.R.F., *Development from Above or Below?* John Wiley and Sons, Chichester, U.K. (1982).

United Nations Development Programme and Economic and Social Commission for Asia and the Pacific, *Power System Planning and Management*; Report on the ESCAP/Government of India Training Course on Power System Planning and Management. Regional Energy Development Programme (RAS/80/001/A 1.7/1983), UNDP and ESCAP, 38 pp. (1984).

World Bank, *Rural Electrification.* World Bank, Washington, D.C., 79 pp. (1975).

World Bank, *India: Economic Issues in the Power Sector.* World Bank Country Study, World Bank, South Asia Regional Office, Washington, D.C., 175 pp. (1979).

World Bank, *Energy Efficiency: Optimization of Electric Power Distribution System Losses.* Energy Department Report No. 6, World Bank Energy Department, Washington, D.C. (1982).

World Bank, *The Energy Transition in Developing Countries.* World Bank, Washington, D.C., 116 pp. (1983).

World Bank, *Power System Load Management Technologies.* Energy Department Paper No. 11, World Bank Energy Department, Washington, D.C., 132 pp. (1983).

DISCUSSION

CHAGAS

As chairman of this Academy I was very happy that twice disarmament came up as a fundamental question. A second point, which I think is very important, is that since we are speaking about the survival of mankind, we have to consider the environment, and this was also brought out very clearly this morning.

Prof. Bernardini, I got the impression that in your exposition of the world coal situation, you spoke more quantity than quality, and I think that one of the problems of coal concerns quality, which, in my opinion, will certainly lead to the need to modify technology to use low grade coal.

Dr. Smith, you showed us a change in the slope of the relationship between gross national product and electricity. Could you go into the reason for this change of slope?

THRING

It may be a little presumptuous, but I am rather thrilled with Professor Demirchian's paper, because I personally have arrived at exactly the same conclusions as the Academy of Sciences of the USSR. He gave us two important conclusions. First, that disarmament is essential for the future of the world and for the solution to energy problems in the poor countries, and second, that they must have non-market type help from the rich countries. If they have to borrow money at the present rates of interest they can never overcome their problems. There are two more conclusions that I want to add. One is that the rich countries have got to set their own house in order and not set an extravagant example in the use of fuels. The other conclusion I think is that it is not possible to have a stable world in the next century unless we do help the underdeveloped countries to solve their energy problems. In other words, it is for the good of our own children in our own countries that we should help them now, even if it is not economical for us.

GOLDEMBERG

Professor Demirchian, I was puzzled not to find in your paper any remarks on conservation and demand management. Now, demand management is very strong in the Soviet Union and this has helped protect it from the oil crisis. I think you should devote some attention to these two elements.

My second question concerns supply options. I got no idea of the relative importance of the different renewable energy sources from your paper.

Malu

A short comment on Prof. Bernardini's paper. It is my opinion that coal is not a credible alternative to oil for the developing countries. The reason is that there are few coal resources in the LDCs, except in China and India. Moreover, coal is one of the most costly forms of energy in terms of its environmental impact; it is also bulky and difficult to handle and requires big investments in infrastructures. Finally, I have a question. Could you please comment on the recent coal slurry developments?

Dr. Demirchian's paper is quite interesting. I am not too pessimistic about energy constraints facing developing countries, provided that they do not just follow blindly what has been done in the developed countries, but try to leap-frog many of the problems.

Coming to Dr. Smith's paper, I am in favour of electricity, but when talking of electricity we have to take into account the cost of electric appliances. You raised many questions in your paper; unfortunately there are very few answers. It would be interesting if you could comment on the problem of load management, energy management, centralized versus decentralized energy systems. I understand that you cannot give general answers but only answers on specific cases.

Desprairies

Mr. Bernardini, looking at one of your tables I was surprised that only three countries, South Korea, Taiwan and the Philippines, were listed. It seems to me that many other countries should be listed, given the fact that coal price is half the oil one, and that many countries have oil-fueled power plants.

My second remark concerns what Dr. Smith said about the adjustment between crude oil and oil products. I maintain what I said this morning. I am confident that the refining industry in the Third World is quite able to adapt itself to yields in the proportion required by demand, and what we have seen in Western Europe in the last five years is exactly such an adaptation. There are no technical or physical problems. There is, of course, an investment problem.

CHOUCRI

I want to be sure that I did not misunderstand. Did you mention, Dr. Smith, that in your view there is the possibility to have a shortage in the refining capacity in the years to come? Is it a question of volume, or localization, or distribution, etc?

PISTELLA

One of the questions more or less explicitly holding the floor today seems to be how we can obtain greater equilibrium in energy trade between LDCs and industrialized countries. It seems to me that we have a certain number of options at hand: diversification of suppliers and customers; different degrees of economic integration of groups of developing countries; development of domestic resources; joint investments or joint ventures to exploit local resources, involving industrialized countries and LDC's.

One more remark. It seems to me that developing countries should welcome any effort by industrialized countries to develop and implement in practice new and sophisticated energy sources (nuclear and photovoltaics, for example). These new alternatives tend to decrease the pressures on more conventional solutions to the energy situation and, consequently, to reduce the prices of conventional energy resources.

BERNARDINI

In answering Chairman Chagas and Dr. Malu, I said that I would discuss not so much what should happen but what is happening. The fact is that developing countries are just beginning to exploit coal. Dirty as it is, they are doing it because in most cases I am sure that if they tried to make it environmentally clean it would cost quite a lot, and they are not willing to forego development for environmental reasons, particularly considering that many developed countries have based their development on environmentally unclean situations. I do not agree with this, I am just saying it is happening. Coal, moreover, is, I agree, not an alternative to oil in many sectors, like transport; on the other hand, it is an alternative in other sectors like electricity production.

Dr. Desprairies asked a question about having a much longer list of countries which could use coal as opposed to fuel oil. I agree, I was just trying to fit countries to categories. However, I would like to point out that in many cases this list could be illusory in the sense that many countries also have other alternatives.

DEMIRCHIAN

Speaking about energy conservation problems, I think there are three aspects to take into account. First of all, the technological aspect. It is a very big problem because it takes into account levels of human skills, technical and training levels. Every process of upgrading is very slow. Second, there is the management problem, which is in part a financial problem. Conservation starts to be an issue when energy prices increase. In the Soviet Union we have kept the price artificially very low. The last aspect is purely financial. The benefits you get from converting a plant must be two or three times the investment.

About disarmament. I think the only way to solve the problem is to discuss it from a rational perspective and not from the political or balance of power points of view. Simple to say, hard to achieve.

SMITH

Mr. Desprairies, with enough investments there is no problem, of course. The problem is what to invest, when and where. I did not mean to imply that there was a diminution in refining capabilities. Over all there is a great surplus in refining capabilities. As I said, hundreds of refineries have been shut down in the last couple of years.

Your question, Dr. Malu, about the answers as opposed to the questions. As you said, it is situation specific in many cases. There are some general answers, keeping to electric power, that we found appropriate for a number of countries in any case. In general, in the stage of development when the electric power system is growing very rapidly, countries may forget demand management, load management, loss management and pricing issues. They would very rapidly exit this growth period if they were to pay attention to some of these issues. Among them there is the long-term training of economists and engineers to understand the economic principles related to load and demand management and to probe changes in the available technologies. I agree with you on the importance of the appliance sector.

LOCAL ELECTRICITY GENERATION

UGO FARINELLI
E.N.E.A.

Electricity plays an important role in the energy scene. In the last decades use of electricity has grown more rapidly than total energy consumption in most countries, and in particular in less developed countries; it has increased in the last few years even where total energy consumption has decreased.

The importance of electricity with respect to other forms of energy lies in its flexibility — both in production and in use — and in its ability to support types of applications (lighting, communications, etc.) that are hardly conceivable without it. In other words, electricity brings about a qualitative more than quantitative improvement in human conditions. This fact is discussed and stressed in other papers in this meeting.

The increase in the use of electricity is brought about in two ways:

1) make more electricity available where it is already consumed
2) bring electricity where it is not yet available.

In this paper we will concentrate on the second. Since all cities have their electrical grid, and all industrial settlements are already electrified, the second point is essentially rural electrification: bringing electricity to villages, isolated farms and houses.

One way to bring electricity where it is not available today is, of course, that of extending the electrical grid, fed by large power stations already existing or by new ones to be built according to the needs and located where it is most convenient for the network as a whole.

A second approach is that of building relatively smaller local networks, to serve a certain concentration of users; these local networks would originally be independent of each other and of the general grid, to which they could be connected in a future time.

A third approach is that of treating each user (or very small group of users) independently with a local generator.

The actual solution may be expected in most practical cases to be a mixture of these approaches, and the choice will be very much dependent on the actual conditions (such as space distribution of potential users, prediction of load curves vs time, status of the network and generating capabilities, local opportunities for electricity generation, etc.).

However, it is important to point out that the choice of the prevailing approach, or of the mix, will have not only economic but also social and political implications.

Fig. 1 shows in a qualitative way the curves of the costs of providing electricity to new users following each of the three approaches mentioned above. Curve 1 relates to the progressive extension of the general grid; curve 2 to the local networks; and curve 3 to independent units.

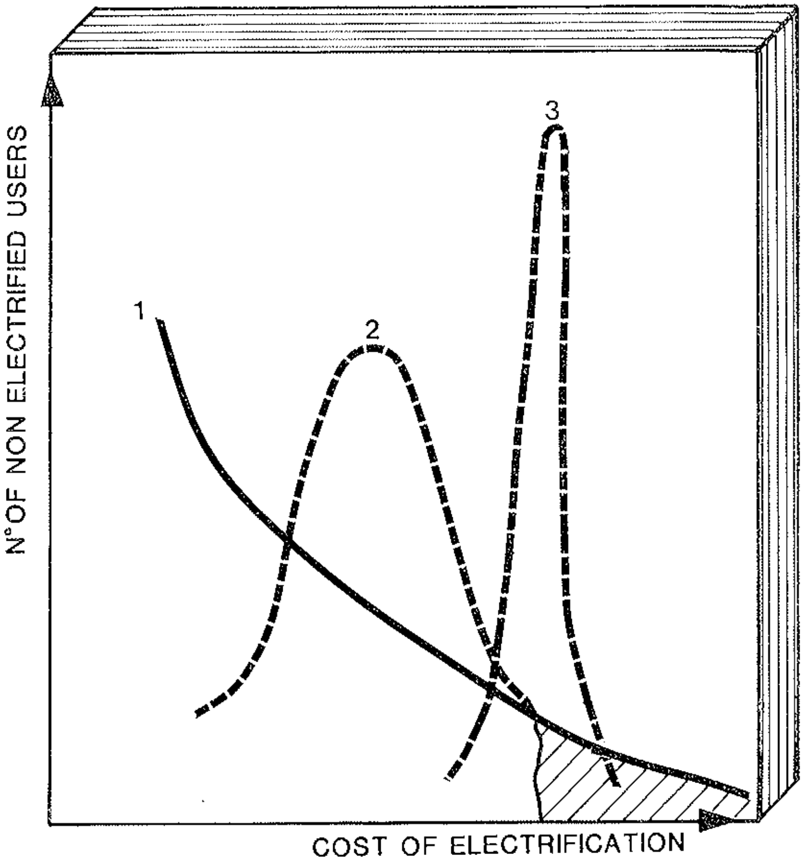
However, there are important differences among these curves.

First of all, curve 3 is practically independent of the sequence in which the various potential users are served. Each intervention is separate from the others and its unit cost is practically constant. Curve 1, on the contrary, implies a more or less fixed pattern of extension of the grid: first serving those who are close to the present low-voltage distribution network, then progressively extending the network. Curve 2 proceeds by lumps; the cost of providing electrictiy to each aggregate is independent from the others.

Another important difference among the curves is their dependence on the power made available to each user. Extension of the grid according to curve 1 is only mildly dependent on power, while strategy 3 implies costs that are practically proportional to the provided power.

The rationale of curve 1 is that at any time it maximizes the number of connected users for a certain quantity of money spent.

However, this is done at the expense of flexibility. In fact a precise sequence is followed, that tends to favour urban concentration with respect to rural settlements. Therefore, pursuing strategy 1 alone will widen the gap between city and countryside, promote further urbanization, depress agricultural production. Although it has been shown that electrification alone will not keep people in the countryside, it is an essential part of any integral development scheme aimed at making rural areas attractive for living.



1 CENTRAL GRID
2 LOCAL GRIDS
3 INDEPENDENT SUPPLIES

FIG. 1. Qualitative curves of electrification for new users.

Therefore, any strategy based on a model of development which is not strictly urban and industrial will require a mix of the three approaches we have mentioned. In such a strategy factors which are not directly economical will also be taken into account (or in other words indirect and hidden costs for society as a whole will be considered for each alternative). Such considerations are actually present in the legislation of many countries. In Italy, for instance, law 308/82 provides, among other incentives, for a public contribution of up to 80% of the cost of installation of systems that provide electricity to "rural dwellings permanently inhabited by the farmer and not connected to the national grid", provided such systems are based on renewable energy sources or recuperation of energy. Photovoltaics is explicitly mentioned as an option.

Several options are available for local electricity generation. Some of the most important or attractive are listed in Table 1. Some of these techniques allow cogeneration of heat and electricity. The well known advantages of cogeneration in terms of global efficiency and fuel utilization can only seldom be exploited in practice in the case of local energy production, because electricity and heat are very rarely needed in the

TAB. 1

LOCAL ENERGY PRODUCTION
500W TO 500 Kw
ALTERNATIVES

DIESEL GENERATORS *

MINI & MICRO-HYDRO

WIND GENERATORS

BIOGAS + GAS ENGINE *

GASSIFIER + GAS ENGINE *

SMALL EXTERNAL COMB. TURBINES *

PHOTOVOLTAICS

* COGENERATION POSSIBLE

same place, at the same time and approximately in the relative proportion supplied by the cogenerator.

Diesel generators are the traditional answer. They are still an economically viable solution when transportation does not weigh too heavily on the cost or availability of the fuel, and when a minimum of technical skill and infrastructures is available locally: in other words, in locations which are not too isolated or too primitive. Lack of foreign currency of course tends to discourage oil-using generators with respect to other solutions.

Mini- and micro-hydro plants may be an economical solution where rather special natural conditions are present. The operation of such plants involves a certain amount of expertise, although recent development in automation will facilitate the diffusion to less developed environments.

Wind generators are again dependent on local availability and characteristics of wind, although this is a more common resource than flowing water resources appropriate for hydro plants. Wind machines of small size are common in some less developed countries, especially for water pumping; their operational record is somewhat controversial. Their use for electricity generation involves some extra problems for maintenance, not so much for the electric generator itself, as for the batteries needed to store electricity for when it is needed.

It is very hard to produce electricity from rural and family size biogas plants such as are common in a number of developing countries, due to the low quantity and inconstancy of gas yield. A digester able to feed a small cogenerator can operate only at farm or village scale, when there is the dung of at least 10 dairy cows (or an equivalent quantity of biomass); the digester must be heated, to avoid shortage of biogas during the cold season, and to obtain a short hydraulic retention time; the hot water produced by the cogenerator or by a solar collector can be used for heating the plant. New design concepts, like the plug-flow, are able to solve many of the problems found in traditional digesters. Problems are sometimes met with the engines, due to the low calorific value of biogas, and the presence of hydrogen sulfide and vapour; all these problems can be solved, but it is necessary to operate with motors specifically designed for biogas, such as some already produced in Italy.

The community digesters, or those working in big animal farms, can be compared with those operating in developed countries, whose technology is well known and developed; in big size plants the main problem is not directly connected with the engines, but with the variations of energy needs (daily, weekly and in different seasons) in front of a constant production of biogas; if there are cogenerators, it is usually rather difficult to find a use for all the hot water.

Coal and dry biomass can be converted into gas with low calorific value (about 1100 Kcal/m^3) which can be fed into internal combustion engines that drive electric generators. Gasification takes place at high temperatures, in lack of air; the gas thus produced must be purified by washing and by filters for powders and tar products that would otherwise damage the engine. This is the weak point of the gasifier-engine system, which requires careful and skilled operators, continuous attendance and ability to maintain the various components (which are anyway not very complex). The use of wood-coal, rather than wood, simplifies these problems, while requiring an intermediate operation on fuel materials. Systems taking these problems into account are commercially available for powers greater than about 15 Kw. The largest 500-1000 Kw systems have dimensions and complexity similar to those of a gas-production plant. The consumption of a typical gasifier/engine/generator system is of the order of 1.5-2 Kg. of wood per Kwh produced.

In external combustion engines an external heat source (combustion of oil, of biomass or even concentrated solar radiation) heats a fluid operating in a thermodynamic-cycle machine. Systems based on different cycles, on various fluids and several heat sources are available. Some of the systems operate on closed cycles with fluids in a sealed loop (water, organic compounds of various types, helium), others on open cycles with air. Sealed systems generally require no ordinary maintenance for the engine, which is however difficult to repair in case of fault. Global efficiencies are generally between 10 and 15%, according to size and type of cycle. Such systems commercially available today include:

— boiler-turbine systems for steam Rankine cycle fed with agricultural wastes for sizes 300-400 Kw and up

— Rankine-cycle systems with turbine using organic fluids, available also for small powers (a few Kw), heat source from combustion or solar.

Maintenance for such systems requires more specialized skills than the steam cycles.

In development stage are systems using Stirling engines, and others employing gas and air turbines. A scheme of a system with an air turbine which is in advanced development is shown in Fig. 2. Such systems may

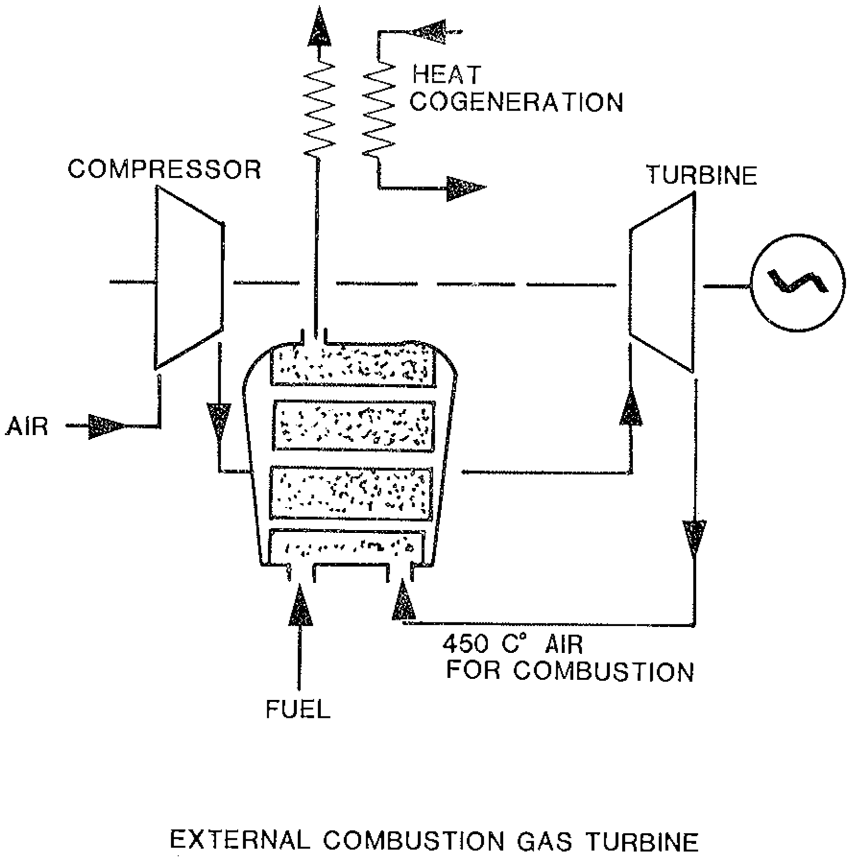


FIG. 2. Schematic diagram of external combustion air turbine system.

be interesting especially for the variety of fuels that may be used; their requirements in terms of operation and maintenance are still to be demonstrated.

Photovoltaic systems are perhaps the most promising in the long term, because they are intrinsically modular (covering the range from watts to megawatts with small differences in specific costs); because they need practically no operation and very little maintenance (with the possible exception of storage batteries, as for the wind systems) and because their innovative nature allows for a great reduction in production costs, as shown by the experience of the last years and the present trends (see Fig. 3). In addition, the photovoltaic industry is rapidly

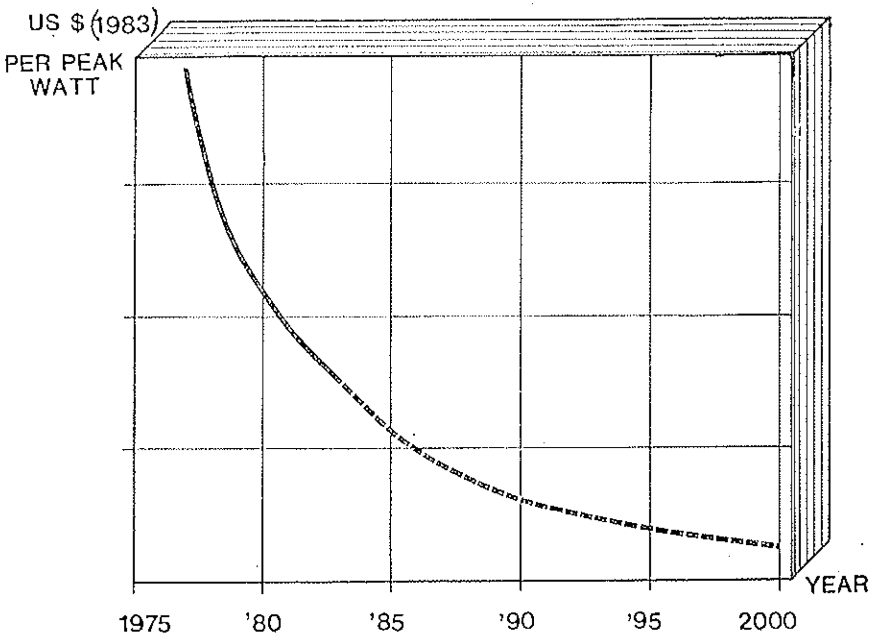


Fig. 3. Observed and predicted prices of p.v. modules.

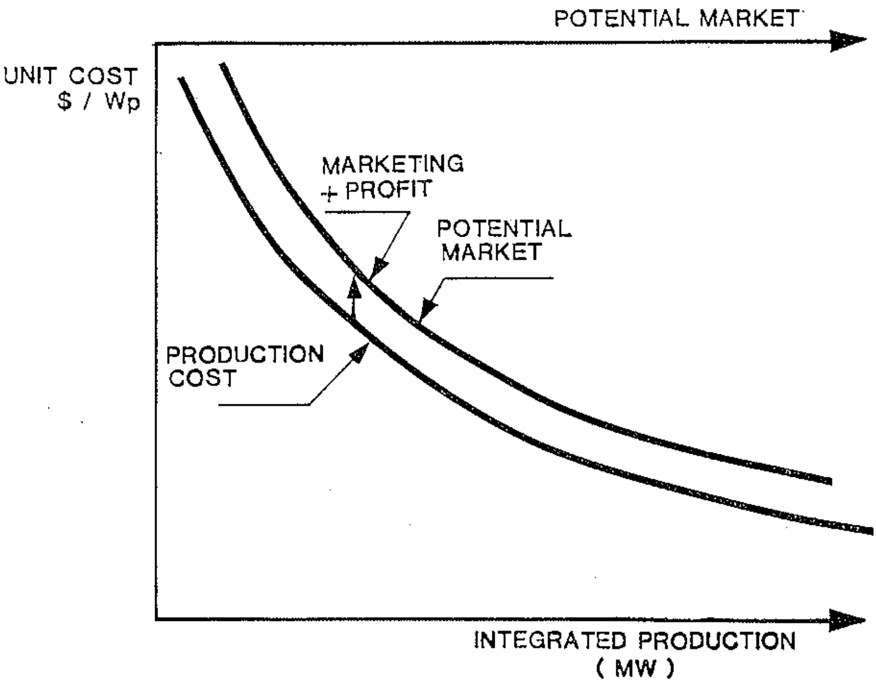


Fig. 4. Comparison of production costs and potential markets for photovoltaic modules.

expanding, because there is an important market even at prices higher than the present ones, because photovoltaic systems have applications for which they have practically no competitor (unattended use in remote locations, such as cathodic protection, radio repeaters, safety signals at sea, electric fences etc.). In this way, production can expand in a free competition for real markets; prices decrease as a result of this expansion, opening new markets; capital is available for new investments (Fig. 4).

THE SOCIO-ECONOMIC SIGNIFICANCE OF RURAL ELECTRIFICATION IN THE LEAST DEVELOPED COUNTRIES: A CASE STUDY ON BLACK AFRICA

L. KONAN
Société Énergie Électrique de la Côte d'Ivoire
Abidjan, Côte d'Ivoire

The Energy Context of the Third World

Although the Third World accounts for a fairly large portion of world energy consumption, in terms of volume, the inhabitants of this part of the world have been and may still be lagging way behind the power consumers of the industrialized countries, if no reaction arises from the international community to oppose that trend.

Indeed, it is estimated that the Third World's part in world power consumption would approach one third in the year 2000 and could reach about 35 to 40% by the year 2020, on the basis of a 25% share in 1978. On the other hand, during the same period, the per capita consumption of the Third World inhabitants will hardly rise from its current 13%, as compared to that of the industrialized countries' inhabitants and reach only 17% at the end of the same period in the best circumstances. Therefore, the volume portion allocated to the Third World is misleading because all the countries which make up the Third World represented 72% of the World population in 1978 and could stand for 77% in the year 2000 and 80% in the year 2020, according to "World Energy Assessment hy the year 2000-2020", a document prepared by Jean Romain Frisch for the Conservation Committee of the World Energy Conference 1983.

Yet, everybody is aware that the Third World owns a very large portion of the world energy resources, be it hydro-based energy, natural gas or oil, let alone agricultural and vegetal wastes which generate biomass, and solar energy or sea thermal power.

This Third World power dilemma is very alarming, all the more as energy has proved to be one of the major driving forces for development today. It is not a mere chance that the joules, ton oil equivalent (T.O.E.) and kilowatthours per capita of inhabitants are considered nowadays as a very significant yardstick to rate the level of development of a country. And yet this self-evident fact seems to raise no alarm in almost all the developing countries, especially in the least developed ones, as they quite often have no power strategy.

It is therefore appropriate to ponder over the energy situation in those countries, especially as regards the rural people, who still account for 80% of the overall populations in these countries.

However, a careful observer will quickly find out that the Third World countries, and especially those from Black Africa, are all confronted with a host of difficulties generated by the development process in which they have engaged themselves. This type of development, as meant by the industrialized countries of the world, implies some equipment and environment which were originally unknown to the Black African countries.

Indeed, whether we deal with housing, health, education, agriculture, communciation means, water or power supply, the people from the developing countries are under the pressure of adapting rapidly and simultaneously in several fields, the methods and practices which they had been used to so far. Such an adaptation process does not spare the people themselves because beyond the technical adjustments, like those experienced in the area of architecture for instance, people must adapt their own mentality and their own behaviour to the exigencies of modernization and development which require some time and some financial resources. So, it would not be an overstatement to say that man himself in the Third World is undergoing a change, hence the slow rate at which his development is taking off.

This context of transition and change, characterized by huge and multiple needs and by particularly limited and scarce resources alike, should be the basis for an appropriate thinking on rural electrification, a genuine factor of development with complex social implications which the man in the developing countries must try to master technically and financially. The rural electrification of the developing countries represents an important and pressing need, whereas the resources required to meet such needs are very limited within the countries and very hard to obtain from foreign countries.

In the energy context of the Third World, changes and adjustments must be performed more rapidly to enable this part of the world to develop. Otherwise, the transition period may turn into a long-lasting, if not permanent state, as indicated by the forecasts quoted above.

Rural Electrification in Black Africa

Such changes and adjustments can be accelerated through the rapid and intensive electrification of areas remote from the large cities, thus enabling a larger portion of the developing countries and least developed countries' populations to take part in the national development process, from the outset.

Unfortunately, the electrification rate in the Third World countries has generally remained very low so far: less than 20%, although this rate may vary largely from one region to the other and from one country to the other. Naturally it is very low in the Least Developed Countries (LDCs). However, it is worth noting that important and continuous efforts have always been made since the States acquired their political independence, to electrify the largest possible number of areas with the means available, despite all kinds of hardships. In fact, here, as in the case of the widow's mite, the effort and sacrifice involved in an act of charity are much more valuable than the act itself. So any action in favour of the less endowed populations in this world deserves our admiration and respect.

In the context of such efforts, several technical methods were experimented in several countries, ranging from isolated diesel plants, capacitive coupling on high voltage lines, local small-scale networks, extension of national HV/MV network to simplified techniques such as single phase distribution networks of the SWER type or two-phase. In order to cover simultaneously as much ground as possible, some systems were implemented, for instance operations such as the one called "*Spider Web Systems*". The main objective of all these efforts is to reduce investment and operational costs while accelerating the rural electrification process despite the numerous difficulties involved.

These difficulties can be recorded under four major headings: scope of the work, physical and technical environment of the areas concerned, human environment and financial means.

Everything remains to be done because rural electrification is generally a very recent process in the Third World. In Black Africa, it only dates back to the late 50's and early 60's, when the Black African countries acquired political independence. To refer only to the case of the Ivory Coast, the number of areas electrified — large cities and rural areas considered altogether — has increased from 14 in 1960 to 513 in 1983, accounting for a growth rate of 4214% which represents the electrification of 25 districts per year on average, in twenty-three years. The high figure of the overall growth is certainly of no great significance, taking into account the small number of districts electrified originally. But the rate of electrification deserves our special attention, considering the modest means available to our country. It is still true that the electrification rate in Ivory Coast is below 50% today, which indicates the actual extent of the effort that remains to be made.

In fact, the limited number of operations performed is due, to a certain extent, to the physical and technical conditions of the areas to service. As a matter of fact, the African countryside is characterized by a series of specific features which do not always comply with the electrification criteria set by the standards of the industrialized countries. In particular, the traditional African dwellings with straw or dry leaf roofs — such easily inflammable materials — are deemed unfit to receive electricity. Besides, large distances between the towns and low level of demand per consumption point — often below 1 KVA per km of medium voltage line — are often a hindrance to compliance with imported criteria such as internal rate of return of the networks. Setting aside the high operational costs involved, isolated diesel plants which are common practice, are not always easier to implement either, due to the unpracticability of the mud-tracks servicing the districts concerned.

Faced with this situation, the developing countries do not have enough qualified local manpower in any of the regions concerned to create a special technology adapted to the local context. This qualitative lack of qualified nationals compels the developing countries to import technologies which are generally too sophisticated and therefore too costly, and in most cases, to import also foreign staff. So there is a pressing need to train people in the necessary skills and to make them reliable. Such actions require of course an appropriate strategy which unfortunately does not appear as an urgent necessity to most countries.

As for those problems relating to the funding of rural electrification, they are both financial and economic. The funds needed to finance projects have indeed become scarce and very costly in the needy countries as well as in the funding countries, due to the current economic crisis and the subsequent confidence crisis; the situation is characterized by an extraordinarily high ceiling of external debts on the one hand, and a spectacular fall of raw material prices on the other hand.

Because of these circumstances, the conditions required by the financing institutions remain drastic and do not take into account the effective needs of the developing countries, the most striking example being the internal rate of return criterion used by the funding institutions to appraise the profitability of a project. How indeed can one justify economically the transmission of power below 1 KVA per km of 33 KV line to service a rural district which is more or less poor? Such appraisal criteria are, therefore, inadequate because they do not take into account the facts in the developing countries whose objective is to fester the social welfare of their populations. Therefore, the issue is to supply these populations in their original environment with the power necessary to improve their internal comfort and safety. The gain expected is to maintain these populations on their lands and by the same token to reduce the rate of rural migration to its strict minimum level.

So one must realize that rural electrification is not designed to fill the coffers of electricity corporations. On the contrary, the electricity corporations implement rural electrification at loss, for the benefit of the social policy established by their respective governments. It is the price to be paid to preserve the dignity of people living in the rural areas, in so far as electrification contributes to keeping them away from the marginal life experienced by those dwelling in the slums and poor districts of the big cities. The value of such a gain is certainly not convertible, even in dollars.

Socio-Economic Advantage of Rural Electrification

The social objective of rural electrification is a justification of efforts made so far and still to come, in order to provide electricity to populations who, apparently, are not prepared to acknowledge that the social value of rural electrification is priceless. Besides, all the parties concerned, namely the local populations, the promoting countries and the international community can draw some advantages from it.

For the rural populations, I shall simply recall if I may, that electricity provides both the rural and urban dwellers with home comfort, public safety and the means to mechanize some traditional activities such as rice husking, water pumping, processing of cereals like maize, rice, sorghum, millet etc. . . ., or the processing of some food products such as tomatoes for instance.

In most countries, the concept of home comfort is becoming a necessity, indeed, as the children born in the cities are now compelled to settle in the rural area because they had to drop out of school prematurely before they could acquire the vocational training and skills required to land a job in the cities. This new generation of farmers is, of course, more demanding than previous ones in terms of home comfort, because they spent several years in the cities. The issue, therefore, is to have them settled in the rural areas and to guarantee a minimum comfort as provided by running water, electric light and the possibility of receiving television programmes.

Outdoor night life, to which this generation has become used, requires that villages be supplied with public lighting very much appreciated in the African countryside.

For this generation, as well as for the previous ones, the television programmes designed specifically for them are a factor of social, economic and cultural progress, in so far as these programmes deal with their permanent sanitary and civic education and enable them at the same time to be informed about new methods of cultivation and the best way to increase their savings.

In the light of these few examples, it is easy to rate the importance of rural electrification for the populations of the Third World in general and Black Africa in particular.

However, the populations are not the only beneficiaries of rural electrification. The State is and will remain the largest beneficiary because the electrification of villages contributes largely to solve a problem which can be termed unexaggeratedly as the Third World plague, rural migration. It is characterized by continuous rushes towards the large cities where the quiet village huts have been replaced by slums and where the peaceful and dignified honest villager becomes very quickly, if he is not careful, a new person and turns into an unscrupulous employee, a drug-addict, a juvenile delinquent, in short, a second-class citizen who tries to survive rather than live, for lack of adequate means. This seemingly uncontrollable thrust to migrate towards the large urban centers is truly the most widely-spread canker in the developing countries. Upon analysis, it appears clear that the temptation of easy money and the yearning for a better life are the roots of rural migration. This is why some parents do not hesitate to encourage their children, boys and girls alike, to migrate to the cities: because they hope to acquire, some day, a commodity or a gadget which they have been dreaming of for a long time, and which they would never acquire otherwise. The result is quite evident: rural migration, motivated by the need for a better social life through the satisfaction of basically materialistic needs, can be a source of alienation, social unrest and even serious, if not tragic, social riots.

For these reasons, it is particularly important for the Third World countries to practice a strong and sustained rural development policy. This is the major reason why power supply, the acknowledged driving force for any modern development process, is a prime concern to leaders of the developing countries. Any success in this field is a factor of social appeasement if not peace, favorable to the design and implementation of infrastructures necessary for the development which any modern country is doomed to; otherwise, it undergoes economic strangulation and disappears as a nation and even as a geographical, legal and human entity.

The international community may also benefit from the successful implementation of programmes relating to power supply to the rural areas of developing countries. As a matter of fact, we must admit the following: the North and the South have now embarked on a joint venture that will keep them bound together as time goes by. As a supplier of raw materials — especially energy related materials — and a consumer of technologies, the South will increasingly contribute to solving some of the most crucial socio-economic problems of the North, such as unemployment which is the talk of the town nowadays. The supply of raw materials, the consumption of technological and manufactured goods can be performed by the South only in a climate of inner peace. Each party, therefore, has a stake in contributing to the survival of the other party, that is to its well-balanced development. Awareness of the contemporary facts, instinct of self-preservation, a sense of social equity and Christian charity call for it.

Prerequisites for Success

I have tried, in my preceding comments, to describe to you the true significance of rural electrification in the developing countries, the reasons behind it and the benefits the developing countries expect to derive from it. Such benefits are primarily of a social nature, but the economic contribution of the farmer is not to be overlooked . Unfortunately, as you may have noticed, the implementation of rural electrification is confronted with many difficulties including, mainly, the maladjustment of the environment to the implementation and appraisal criteria selected, and the scarcity of the financial resources needed for funding rural electrification.

However, just as the developing countries did endeavour to search for the most appropriate technical methods, even when imported, likewise, one cannot remain indifferent to the difficulties which are still hampering the accelerated growth of rural electrification: several approaches could be tried.

In this respect, it would first be advisable for the developing countries to establish, for their own benefit, and wherever no such thing exists yet, a developement strategy for the rural environment identifying precisely the position and the role assigned to energy. It would then be possible to define the role of electricity in the development of that environment. However, it would appear from the preceding comments that, despite its major role as a social and economic factor, electricity alone cannot solve the energy problems of the rural areas in the developing countries. All-inclusive power systems must therefore be designed and established to define the scope of the problem. At this stage, the so-called new energy sources are fully gaining ground. First of all, because the populations are more familiar with them, then, because several processing methods of these power sources are inexpensive. Besides, such kind of energy which can be generated at a small scale level may be better adapted, for some uses, to the needs of the developing countries' rural people. Therefore, it would be very profitable to upgrade them. Here again, the role of the industrialized countries is fundamental, because although the cleverness of the local populations may help in setting up some workable systems at reasonable costs — for instance in the case of bio-gas — only the industrialized countries who own the technology and financial resources can and must design, in most cases, the equipment needed to process these energy sources. This applies for solar energy, geo-thermal power, wind power etc. ... The main point is that such equipment should be adapted to the needs and the control and maintenance skills of those for whom they are intended.

As for manpower, adequate measures must be taken not only to train local people in the skills required to operate those systems, but also to make them liable by assigning them specific objectives to be reached within set deadlines. Performance checks must help record periodically the progress made, identify possible lacunes and take the necessary corrective measures. The industrialized countries can assist the developing countries considerably for manpower training either by increasing the number of vacancies reserved for developing countries' students in their schools, or by contributing to the funding of appropriate schools operating in the developing countries and by supplying instructors.

Appraisal criteria of socially trended investments such as rural electrification should be alleviated to facilitate their implementation. Indeed, it is important to understand that, considering the very serious state of under-development in the developing countries, the development action to be undertaken must be considered in the same spirit as the reconstruction action carried out after World War II to restore Europe. There is no price to people's survival. Therefore, it would be a crime to subject it to artificial criteria such as the internal rate of return of a development project.

However such cost reduction efforts will be insufficent and the rural areas' rate of development will continue to be very slow as long as the industrialization process of the developing countries remains as low as it stands now. Indeed the advantages of local manufacturing are quite obvious, namely, greater reduction of costs due to savings on transport, induced effects, added value, better adaptation to the local context, standardization of equipment, the latter being impracticable in the case where equipment is imported from various countries having their respective technical standards.

Conclusions

As a conclusion, it must be borne in mind that rural electrification, a necessary driving force, is a source of social peace and harmony and an illustration of the developing countries' spirit of fairness as regards the distribution of the benefits derived from the development process. Its social role is of paramount importance.

Therefore, it appears quite imperative not only to implement rural electrification but also to expedite such implementation and reinforce it, because it is urgent and vital for the developing countries' inhabitants to revert to present modern trends, otherwise they will soon be doomed to remain only marginal citizens in this world, to the prejudice of their dignity as human beings.

Unfortunately, the success of rural electrification depends on various factors which hinder its implementation. Some of these factors are external factors such as high investment costs, scarcity of funds or inadequacy of the economic appraisal criteria, but other factors are primarily inherent to rural electrification itself, for instance, insufficient number of people coupled with a dire lack of responsible skilled local staff and the absence of extensive industrial activities.

Once it is associated with the valorization of new power sources, rural electrification can contribute efficiently to meeting the total power demand in the rural areas.

But complete success may be considered only through the international community's awareness of the issue, through genuine cooperation between the North and the South, unseparable partners in the development joint venture which will make them God's people elect or damned if their decisions are guided solely by their selfishness.

DISCUSSION

LEPRINCE RINGUET

Monsieur Konan, au sujet de l'électrification en Côte d'Ivoire, vous avez dit qu'elle doit être associée à une action culturelle où la télévision joue un très grand rôle. Quelle est la proportion de villages électrifiés qui possèdent au moins une télévision? La télévision est-elle un centre de rassemblement?

KONAN

Oui, un poste est largement suffisant dans un premier temps pour les villageois. C'est vraiment ce qu' il y a de plus communautaire.

CHOUCRI

I would like to underline a point which has been made by Mr. Konan. He said that in Africa there are practically no borders between countries. There is no way of controlling the migration flow from one country to another. The combined flows of refugees plus migration are uniformly placing pressures on most of the African countries and placing additional constraints on the development of options before us.

BLANC-LAPIERRE

Monsieur Lambert, combien d'années pensez-vous seront nécessaires pour réaliser les interconnections principales du réseau électrique africain que vous nous avez présenté?

KONAN

Le financement pour ce projet est chose faite. C'est donc maintenant un problème d'efficacité de travail et, si tout va bien, en 1987 ce programme sera réalisé.

LEMKECHER

Je voudrais savoir si autour de ce nouvel approche au procès d'électrification en Côte d'Ivoire on est en train de mener des études socio-économiques de longue durée, qui en analysent avant, durant et après l'impact profond. Ceci, d'autant plus que le phénomène de l'exode des pays voisins risque, au bout d'un certain temps, de créer des problèmes peut-être insolubles.

SUAREZ

Je crois que nous devons tenir en grande considération la demande de collaboration et de solidarité, que présente ici l'Afrique par la voix de Monsieur Konan.

ZEGHBIB

Je voudrais revenir sur un point qu'a souligné Monsieur Konan, concernant le notion de rentabilité. Si on applique les critères économiques-financiers, il n'est pas toujours, pour ne pas dire souvent, rentable de faire l'électrification rurale. Il ne faut pas se limiter aux aspects strictement économiques, il faut voir aussi l'impact et les bénéfices sociaux que l'électrification comporte. Un vieux paysan algérien a répondu à la question: « Qu'est-ce que c'est pour vous le progrès? » en disant: « Le progres! C'est le goudron et l'électricité ».

KUWAIT's EXPERIENCE IN SOLAR ENERGY

ADNAN AL-HOMOUD
Energy Department, Engineering Division
Kuwait Institute for Scientific Research
Safat, Kuwait

Introduction

Kuwait is a small country that stands on the north-western corner of the Arabian Gulf between 28° and 30° N latitudes, and 46° and 48° E longitudes. It has an area of about 19,000 square kilometers. Because of its location it enjoys long durations of clear days with high levels of solar insolation. On the average, the intensity of solar radiation on a horizontal surface varies from 480 W/m^2 on a typical December day to 700 W/m^2 during June with peak values of 900-950 W/m^2. The direct normal solar radiation has been recorded to have reached values of 950 W/m^2 on the coastal areas and 1000 W/m^2 for the inland. Figure 1 shows the amount of available solar energy in Kuwait.

Along with the high level of insolation, Kuwait suffers from harsh climate, with outside temperatures touching the lower 50's in the summer months. Figure 2 represents the temperature variations throughout the year as well as the average wind speed. According to the Ministry of Electricity and Water 1983 report the energy and water consumption has tripled between 1973-1982. Figure 3 illustrates the development of the maximum load during the period 1978-1982, indicating that the peak load occurs during the summer months most of which is due to airconditioning systems. The same trend is applicable for water consumption as seen in Table 1.

Realizing these facts the Energy Department was initiated in 1976 at the Kuwait Institute for Scientific Research (KISR) to develop solar energy as a viable alternative source of energy that could help prolonging

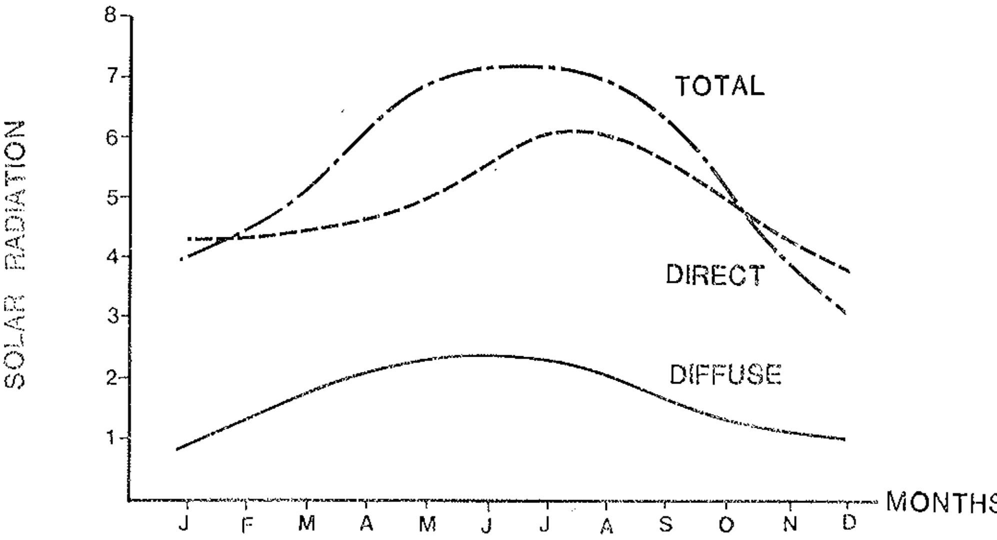


FIG. 1. Monthly average total, diffuse and direct radiation in Kuwait, 1978-80.

the life cycle of oil. To carry on such a task it is necessary to demonstrate the feasibility of extensively employing solar energy applications in Kuwait in various fields, and at the same time identify possible problem areas. As demonstrated previously much of the nation's energy is consumed in providing cooling and water; therefore the department has identified these areas for intensive research. The Energy Department in Kuwait is involved in the following areas of research:

1. Meteorological Data.
2. Solar Cooling and Heating.
3. Solar Thermal Electric Generation.
4. Desalination with Solar Energy.
5. Photovoltaic Applications.
6. Others: (i) Agricultural Applications of Solar Energy; (ii) Wind Energy; (iii) Infrared Sky Radiation Cooling.

It is crucial for research and development (R&D) to build up the local manpower in the field of solar energy to enable the department to keep up with the international development as well as initiate its own research programmes pertinent to the local needs.

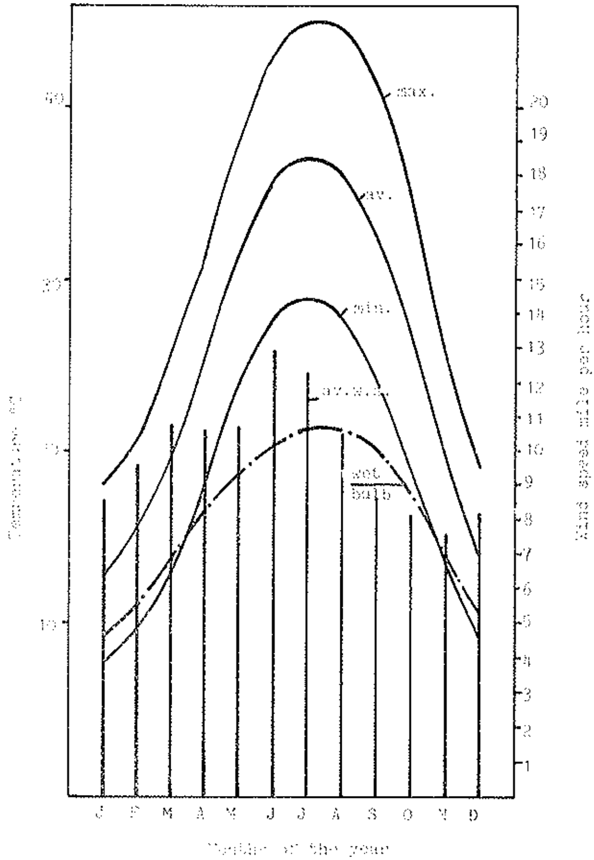


FIG. 2. Monthly average of maximum, minimum and mean values of temperature and wind speed in Kuwait, 1958-1980.

1. METEOROLOGICAL DATA

An important base for all solar applications is a weather station. It is necessary to establish an accurate data base for solar radiation measurements and the collection of relevant meteorological data. An accurate data base will enable a proper assessment to be made for solar energy's contribution to the nation's total energy supply.

The meteorological station at the Energy Department has several instruments measuring the total, diffused and direct radiation on an

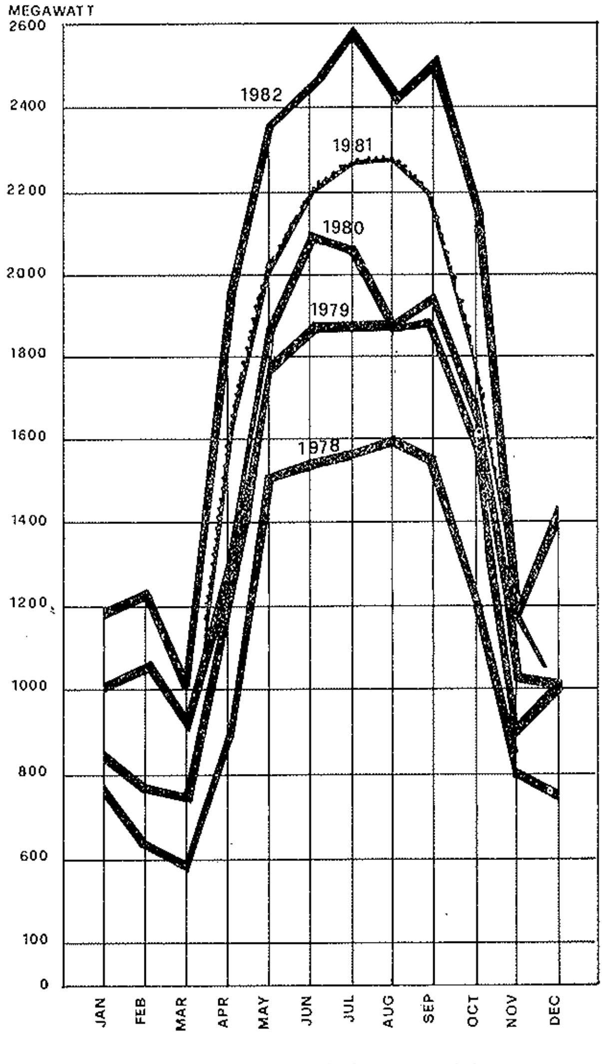


FIG. 3. Maximum load during 1978-82.

'ABLE 1 — *Total Production and Daily Average Production of Fresh water During* 1975-82 (in M.I.G.).

Months	1975		1976		1977		1978		1979		1980		1981		1982
	Production	Daily Average	Production	Daily Average	Production	Daily Average	Production	Daily Average	Production	Daily Average	Production	Daily Average	Production	Daily Average	Production
nuary	730.1	23.6	882.3	28.5	1035.0	33.4	1328.3	42.8	1540.7	49.7	1602.5	51.7	1627.8	52.5	1863.9
ebruary	657.7	23.5	855.2	29.5	1069.5	38.2	1309.6	46.8	1473.2	52.6	1548.2	53.4	1507.4	53.8	1709.8
arch	818.9	26.4	962.6	31.1	1243.1	40.1	1488.0	48.0	1703.3	54.9	1807.2	58.3	1785.2	57.6	1900.9
pril	923.3	30.8	1061.2	35.4	1320.1	44.0	1683.2	56.1	1855.5	61.9	2074.0	69.1	2100.6	70.0	2364.0
ay	1041.9	33.6	1279.0	41.3	1545.8	49.9	1821.9	58.8	2088.5	67.4	2267.9	73.2	2251.7	72.6	2614.4
une	1068.0	35.6	1408.6	47.0	1598.7	53.3	1945.4	64.8	2153.8	71.8	2322.1	77.4	2296.2	76.5	2559.3
uly	1140.4	36.8	1415.3	45.7	1699.7	54.8	1940.3	62.6	2240.6	72.3	2049.6	66.1	2443.8	78.8	2969.7
ugust	1149.6	37.1	1459.7	47.1	1663.4	53.7	1987.2	64.1	2169.1	70.0	2160.4	69.7	2439.7	78.7	2822.7
eptember	1154.4	38.5	1349.4	45.0	1700.4	56.7	1893.2	63.1	2175.3	72.5	2100.9	70.0	2387.5	79.6	2722.6
ctober	1078.1	34.8	1371.8	44.3	1651.2	53.3	1995.0	64.4	2159.6	69.7	1995.7	64.4	2200.4	71.0	2663.6
ovember	961.3	32.0	1182.6	39.4	1414.6	47.2	1678.6	56.0	1820.6	60.7	1846.7	61.6	2083.5	69.5	2162.9
ecember	877.0	28.3	1152.3	37.2	1379.5	44.5	1682.4	54.3	1703.6	55.0	1704.9	55.0	1986.4	64.1	2082.6
otal Production	11,600.7		14,380.0		17,321.0		20,753.1		23,083.8		23,480.1		25,110.2		28,436.4
aily Average per Year	31.8		39.4		47.5		56.9		63.2		64.2		68.8		77.9

hourly basis throughout the year. Readings for wind speed, wet- and dry-bulb temperature, sunshine hours and relative humidity are also monitored. Data for the years 1977-1982 were entered in a computerized data base by which a statistical study has been performed. In the meteorological station is a section for the radiation calibration laboratory in which the radiometers in Kuwait can be calibrated. Figures 4 and 5 are some of the data produced by this station.

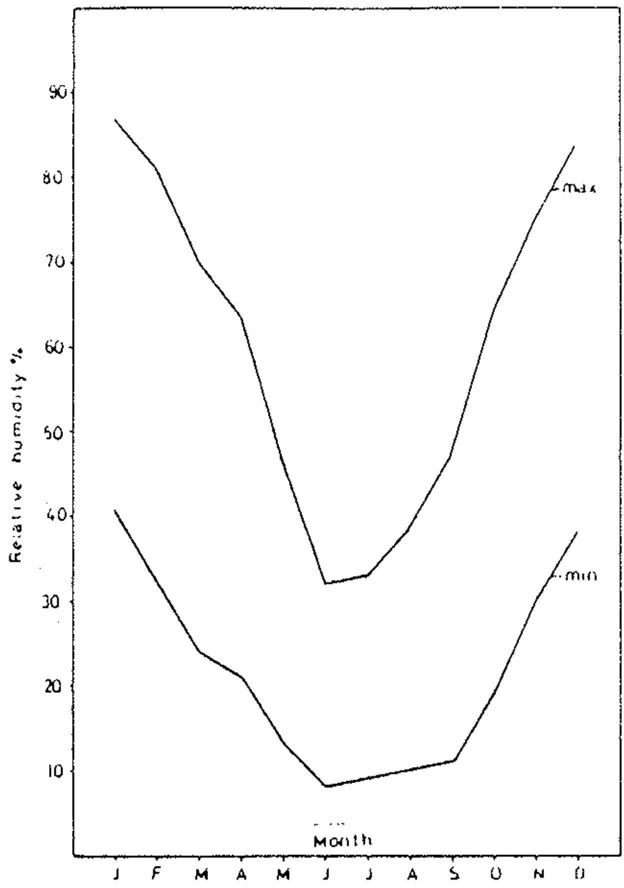


FIG. 4. Maximum and minimum values of relative humidity in Kuwait, 1957-80.

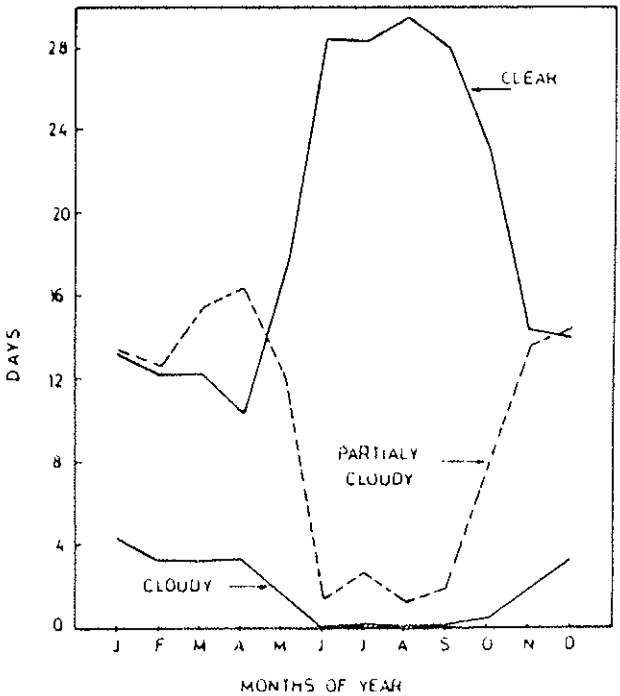


FIG. 5. Mean number of days of clear, partially cloudy and cloudy in Kuwait, 1957-80.

2. SOLAR COOLING AND HEATING

2.1. *Solar Mobile Home*

A 3-ton absorption ARKLA unit was used to provide cooling and domestic hot water to a two-room prefabricated unit, which was used as an office space. The results of this study showed that the first generation absorption airconditioner operated at less than 50%, and that the first generation of flat plate collectors with black-paint-covered absorber are not sufficient for solar cooling.

2.2. *Solar House at KISR*

The house was built with the passive features including orientation, insulation and double-glazed windows and shading. It was built to further develop the know-how in the field of solar cooling and heating since it was provided with water and air solar heaters. Only recently a photovoltaic system was installed to provide electricity for lighting and the parasitic power for pumps, fans, etc.

The house is constructed on a 400 m^2 area, 150 m^2 of which is used for offices and/or living area while the rest is being used for the mechanical and electrical hardware. Cooling for the house is provided by a 7-ton lithium-bromide absorption cooling system. The machine room also houses a domestic hot water system, auxiliary boiler, thermal storage tank, air-handling unit, rock bed storage, and controls. Data acquisition system (DAS) is used to monitor and collect data on the performance of each system individually.

2.3. *Solar School*

A solar absorption cooling system was installed in a kindergarten as a joint project between KISR and Ministry of Electricity and Water (MEW). The system provides cooling for six classrooms with a total area of 500 m^2. The anticipated peak cooling load is 30-ton of refrigeration, for that four 10-ton Yazaki chillers are used.

The heating devices are 180 solar flat plate collectors each with a nominal area of 2 m^2 and active area of 1.91 m^2. These collectors were installed on the roof of the classrooms and connected to a 25 m^3 hot water storage tank.

2.4. *Ministry of Defense Solar Regional Office at Mushrif*

This is a joint venture between KISR and Ministry of Defense (MOD). It includes the utilization of solar to provide cooling, heating and electricity for a 630 m^3 facility for the Military Installation Division.

The system consists of a 20-ton absorption system for cooling and a 50 kWp photovoltaic system. The building will also be equipped with a diesel engine as a backup system. The cooling load of this facility was reduced by taking some passive measures into account, such measures include orientation, insulation, double glazed windows, lighting and shading. A major output of this project is the assessment of suitability and reliability of stand alone photovoltaic system as a source of power generation.

2.5. *Solar Cooling Assessment*

This project forms the first phase of the five-year plan for solar cooling in Kuwait. The project involves critical assessment of commercially available and also future expected systems for thin potential large scale usage in Kuwait. The project's recommendations are for solar cooling applications for different types of buildings in Kuwait, the R & D work plan proposal and also commercial production ventures which could be initiated by Kuwait based industry in this area. The assessment recommends that "low temperature $ 4000/peak kW Rankine systems are not economical, Munters Environmental Control (MEC) systems (also known as dissicant cooling) are neither economical nor practical, solar absorption is the most promising among competitors, all solar cooling systems are not competitive with conventional ones, water-cooled photovoltaic driven standard cooling systems will compete with solar absorption cooling if photovoltaic system cost drops below KD. 25,000/peak kW (i.e. $ 8,500/peak kW), and that photovoltaic driven cooling system will be competitive with conventional airconditioning if photovoltaic system cost drops below $ 4,000/peak kW", (Fig. 6) (Bishara *et al.*, 1983).

3. Solar Thermal Electric Generation

One way of conserving conventional electricity is to use solar cooling vs. conventional cooling since a solar-driven absorption system consumes less energy than the latter; another way is to produce electricity from the sun. The first method has been tackled in the above mentioned program of solar cooling, the way is being tackled by the 100 kW_e/700 kW_{th} Sulaibiah project.

The project was initiated to be a stand alone integrated Food/Water/Power Complex which utilizes a 100 kW_e solar thermal power plant as a prime mover. The implementation started in 1979, the first prototype collector was tested in October 1979, the power plant installation started in April 1980 and the operational test started in March 1981. The plant output is 100 kW and its reject waste is 700 kW, which is used to power a 10 m^3 Reverse Osmosis Desalination unit, a 50 m^3 multistage flash desalination plant, salt gradient solar pond and a convective cooling pond.

The solar conversion subsystem of the power plant paraboloid con-

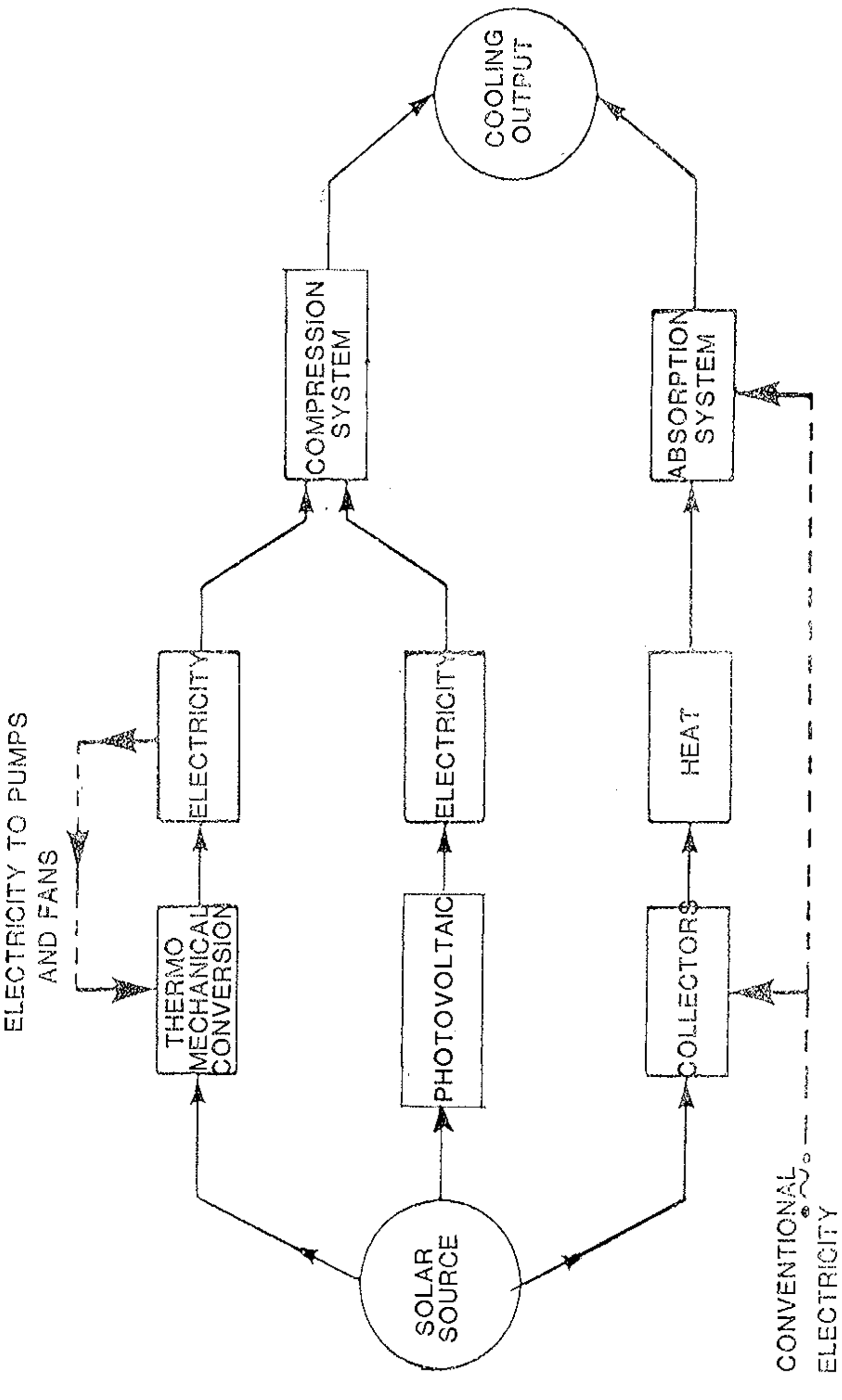


Fig. 6. A diagram of the cooling methods for the solar cooling assessement study.

centrating collectors each has a 5 m diameter and a spherical absorber in the focal point 10 cm in diameter. The heat transfer fluid is a synthetic oil. The energy conversion subsystem consists of a toluence turbine Rankine Cycle (see Fig. 7).

4. Solar Powered Multistage Flash Desalination Plant (MSF)

4.1. *Desalination of Seawater - KISR Solar Multistage Flash Desalination Plant*

The use of solar energy for desalination for Kuwait and other parts in the region can be an alternative energy source as world-wide fossil fuel supplies begin to lag the demands.

The KISR solar MSF desalination plant is designed to produce 10,000 liters per day utilizing line focusing collector field, thermal storage and MSF desalinators. The collectors field consists of modules of line focusing collectors mounted on a north-south orientation. The modules are equipped with sun sensing and tracking system (see Fig. 8).

Several applications of photovoltaics have been deployed, some of which have been mentioned previously (sections 2.2 and 2.4) and others are traffic light applications, comparative testing of different modules, dust effect on panels, mobile battery charger.

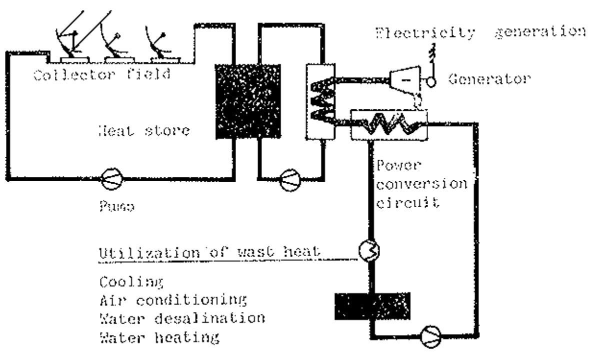


Fig. 7. Schematic diagram for the KISR 10 kW solar thermal power plant.

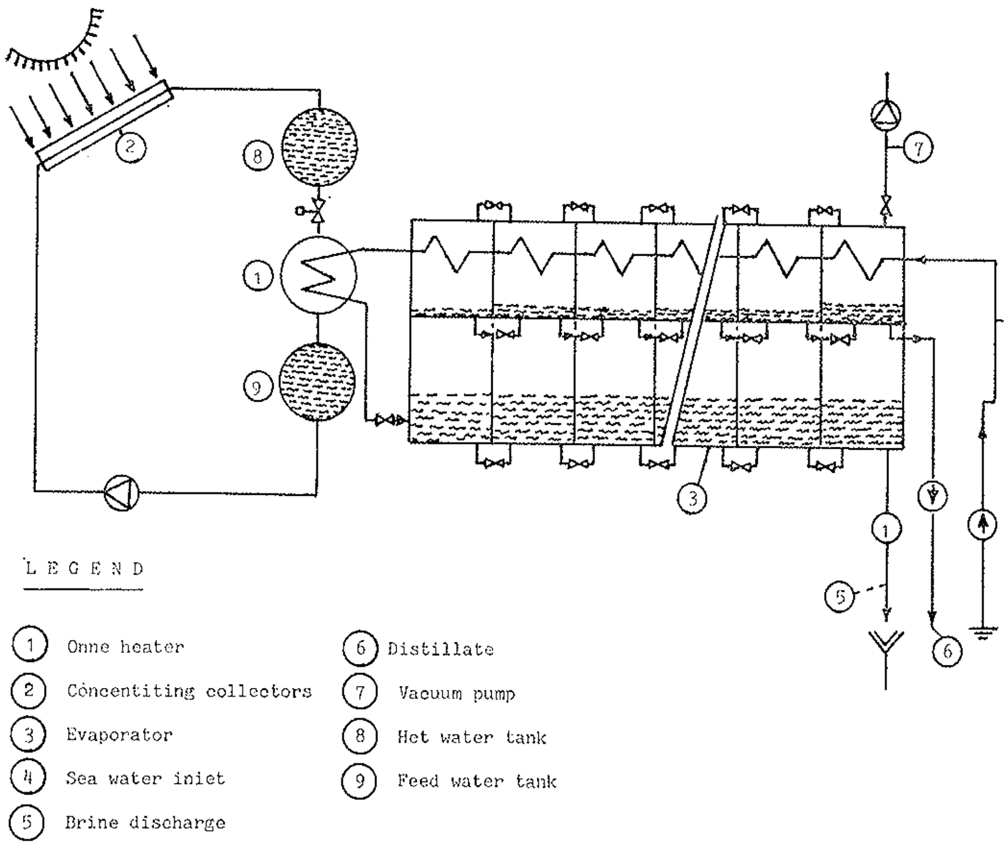


FIG. 8. Schematic for KISR's solar multistage flash desalination plant.

6. OTHERS

6.1. *Agriculture Applications of Solar Energy-Cooling of Greenhouses*

Several greenhouse prototypes have been designed to operate under the extreme environmental conditions of Kuwait, five of which have been built with passive features such as partially sunken structures, movable insulation and reflective inside coatings. By reducing heat transfer through various surfaces, the cooling load of greenhouses is substantially curtailed. The amounts of radiation allowed to enter the greenhouses are only those which are absolutely essential for plant growth.

Other greenhouses are especially designed for the integrated Food/Water/Power system, (Fig. 9). The heart of these greenhouses consists of line focusing concentrating collectors in a parallel series. The solar collectors are parabolic cylindrical models with a control system which automatically positions the collectors towards the sun. The thermal energy withdrawn by the absorber pipes helps keep temperature at a lower level than that in greenhouses with conventional shading. The excess heat received by the greenhouses is utilized as an input heat into another system such as desalination. This process allows for cooling the greenhouses while providing the needed energy for the water desalination process.

6.2. *Wind Energy*

Only recently wind has been thought of as an available source of energy

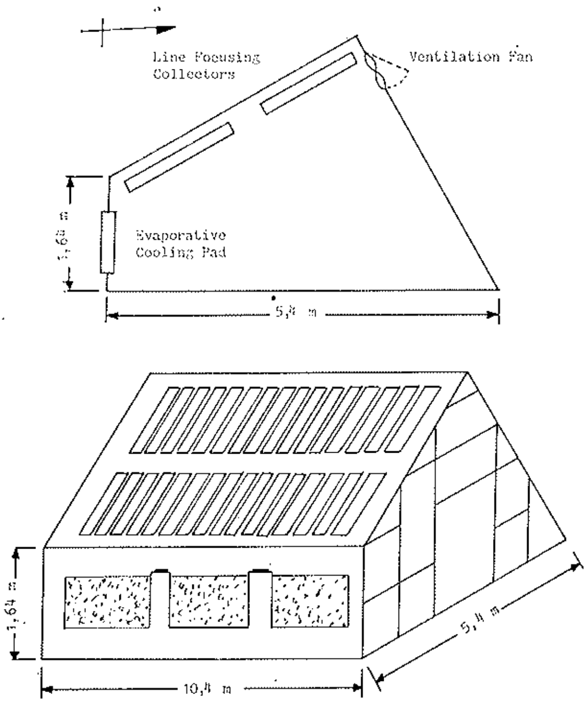


FIG. 9. An active solar greenhouse utilizing line concentrating collector for shading and rejection of excess heat.

in Kuwait. The data that was collected by the Civil Aviation Weather station is not complete/accurate. The Energy Department is currently working on an assessment of wind energy in Kuwait. Data is being collected from three different locations in Kuwait and subjected to a statistical analysis. Preliminary results indicate that wind has a characteristic similar to solar energy in that they both peak during the high energy demand period and could be an available source of energy.

6.3. *Infrared Sky Radiation Cooling*

The potential of the radiative heat transfer to the sky for cooling purposes is examined in this project. This potential is highly elevated in the arid land such as Kuwait's due to the lack of physical prohibitive barriers like water vapour, carbon dioxide and ozone. It is known that in a dry environment free of carbon dioxide and ozone the atmosphere will be transparent and objects exposed to the sky could lose heat via radiation in the wavelength range between 8 and 100 microns.

This concept could be used as a passive cooling measure for houses with flat roofs.

Solar Energy Readiness in Kuwait

Kuwait, being an energy exporter, faces a characteristically unique set of circumstances that could affect the prospects of commercialization of solar energy technology in the years to come. They include two major factors: (i) The availability of low cost petroleum products, subsidized electric energy and its steady supply both appear to reduce the chance for competition from the already expensive solar collection and utilization equipment, and (ii) The relatively high income of Kuwait compared to the cost of energy further reduces the economic incentive needed for adopting alternative energy systems.

These factors, however, appear to be balanced by another set of circumstances that could have a positive effect on commercialization prospects. They include:

1. The availability of the capital needed for the larger initial investment associated with solar energy systems.

2. The awareness of the Kuwaiti public of the need to conserve petroleum because of its vital importance for the well-being of the nation.

3. The progressive attitude of the average Kuwaiti and his futuristic taste in home designing, equipment and technology adoption. This trend may prove to be helpful in adopting solar technology once he is convinced of its reliability of performance.

4. Governmental efforts in conserving the national oil resources and encouraging the utilization of other energy sources including solar energy. This effort results in the selection of a number of private and public buildings for the demonstration of solar technology in heating and cooling to familiarize the public with its potential.

5. Existence of an industrial base in Kuwait that has the potential of manufacturing solar collectors and other solar system components.

The high energy consumption for airconditioning and desalination and the tendency for increased need for both in the time of the year when solar energy is most abundant, allows for efficient equipment utilization.

Conclusion

Kuwait is an energy exporter with an expanding economy and high rate of increase in energy consumption. All the energy it currently uses, to power its economy and desalinate the water it utilizes, comes from petroleum products.

Energy demand increases considerably during the summer because of the heavy demand for airconditioning and desalination, at the same time solar insolation is most abundant. This indicates a natural relation between the availability of solar energy and peak power demand.

The potential of utilizing solar energy as the prime energy source for power/water/food complexes for small remote communities may prove to be a most useful concept in Kuwait and other countries in the Arab World. In such systems electric power generation, water desalination and specially designed greenhouses could use most of their energy needs from the sun.

The unique energy and economic circumstances in Kuwait could in the long run prove to be positive for the development and commercialization of solar technology in Kuwait. This is primarily because of the availability of capital, awareness of the need to conserve the natural oil resources, government policy for energy conservation and effort to encourage the development of alternative energy sources.

ACKNOWLEDGEMENT

The author wishes to express his thanks to the staff of the Energy Department for their contribution in compiling the information about the various projects cited in this paper.

REFERENCES

Ministry of Electricity and Water, 1983.

BISHARA A., DEBS A. and SAYIGH A.A.M. - Paper presented at the First Arab International Solar Energy Conference held in Kuwait December 3-7, 1983.

FAMILY INCOME DISTRIBUTION AND ENERGY DEMAND; POLICY IMPLICATIONS FOR DEVELOPING COUNTRIES

RICHARD EDEN
Cambridge Energy Research Group
Cavendish Laboratory, Cambridge, UK

Abstract

The total direct consumption of energy by households varies widely both in its magnitude per household and as a percentage of total final demand for different countries. This variation is discussed with particular reference to the United Kingdom and Brazil. The discussion is extended to the changing size and character of direct energy demand per household for groups at different income levels in each country. It is observed that increased household income leads to a preference for higher quality fuels, such as electricity and LPG in Brazil, and to improved efficiency in use in the UK. In both countries the demand for gasoline per household increases proportionately faster than income.

The indirect use of energy by households arises from the purchase of goods and services. This appears to be more closely related to income than is the case for direct energy use. However, there may be a quality effect through which the value of goods increases faster than the energy to make them. Such a feature would assist towards reducing the growth of indirect energy use as incomes rise.

1. *Introduction*

The relation between energy demand in individual countries and their economic growth has been varied and uncertain, particularly during the past decade; thus it could be used to illustrate the diversity between countries rather than their similarities. The adjustment to higher energy prices in some developed countries has been so successful in reducing energy demand per unit of national output, that it casts doubt on the time-honoured belief that economic growth implies a corresponding growth in energy demand. However, in other countries, including many developing countries, the adjustment to higher energy prices, and the consequent disturbance to world trade, has proceeded more painfully through lost economic growth and higher unemployment.

In this presentation, I shall discuss energy demand and development, with special reference to family income distribution. We are all familiar with the inequalities between nations of per capita wealth, and the corresponding per capita energy consumption. In the poorest nations this is only one per cent of the per capita energy used in the richest nations. However, the relation between income and energy demand for different levels of wealth within each country has received much less attention. There were important pioneering papers by Herendeen [1, 2] and Tanaka [1] in the 1970's, on household expenditure and energy demand in the United States and in Norway. More recently Behrens [3] has made similar studies for Brazil. I shall be quoting from these papers later in this presentation, but my main objective is to point to the importance of this type of study to energy planning in developing countries. In particular, such studies can help identify the serious problems that scarce or expensive energy can cause for the poorest families, and they can indicate also the levels of income at which the growth in household energy demand begins to have a major impact on national requirements for fossil fuels and electricity.

Before turning to family income distribution and expenditure on energy, I shall briefly discuss international comparisons of energy demand and economic growth, since some of the problems that are raised by this global picture point to the need for more detailed analysis within countries. One aspect of this analysis, to which I shall turn in later sections, is the relation between family expenditure and energy demand, including both the direct consumption of fuel and electricity, and the indirect use of energy through expenditure on goods and services. This analysis illustrates both the global diversity between nations and the diversity amongst individuals and families within nations. It is this diversity of present status and of future needs that lies at the heart of the problem of energy and development, and which precludes any single or simple solution.

2. *Energy demand and economic growth*

The relation between commercial energy demand and economic activity is illustrated in table 2.1 for selected countries and groups of countries. We see that India has a high energy intensity, at 26 MJ per US dollar, compared with other low income countries — a feature that may be partly due to the availability of indigenous coal and its extensive use in India. The intensity of the group of middle income countries, at 21 MJ per dollar, is very similar to the average of India and other low income countries, though the middle income group has six times the average per capita income of the low income group. The richer group of industrial market economies has seven times the average per capita income of the middle income group, but the average energy intensities are similar. However, the intensities for the United States and Canada are approximately twice the average for other industrial countries, so the latter appears to be significantly below (about two-thirds of) the average for the middle income group (but see our comments below on exchange rates and purchasing power parities).

TABLE 2.1 — *Income per capita and energy demand per GNP.*

	GNP per capita in 1980, US dollars [a]	Energy [b] per capita GJ	Energy per GNP MJ per US dollar
India	240	6.2	26
Other low income market economies	230	3.1	14
Middle income [c] market economies	1400	29	21
Industrial market economies	10320	220	21
Brazil 1980	2050	32	16
United Kingdom 1980	7920	157	20

Source [4]: World Bank Development Reports 1982, 1983.

Notes: [a] At market exchange rates.
[b] Commercial energy demand, GJ, gigajoule.
[c] $ 420 to $ 4500 per capita.

The energy intensities of the low income and middle income groups of countries in 1980 were similar to their values in 1960, when expressed in terms of 1980 dollars, but for the industrial market economies the average intensity showed a decrease of 18 per cent. This improvement in apparent energy efficiency took place almost entirely in the period after the 1973 energy crisis, and there have been further gains since 1980. Some of this improvement can be attributed to a response to higher prices, which (on average) almost doubled in real terms for the final consumers in major industrial market economies. Other contributions to improved energy efficiencies are due to continuing technological progress, to the saturation of demand for cars in some countries, and to structural change, partly accelerated by the higher energy prices and, more recently, by the world economic recession.

The energy intensity for an individual country is more strongly affected by changes in exchange rates than it is for the large groups mentioned above. Thus in 1980, because of the strength of Sterling in that year, the UK energy intensity expressed relative to GNP in US dollars was low compared with its general trend; in general the energy intensity for the UK is found to be high compared with other industrialised countries. In contrast, Brazil has a low energy/GNP ratio compared with other middle income countries.

If we were to use exchange rates based on purchasing power parities, rather than market values, the apparent dollar income per capita would be increased twofold or more for most developing countries. The consequent energy intensities based on commercial energy demand would then be much lower for the developing country groups than for the industrial group. There is a compensating effect due to the higher proportion of "non-commercial" energy in the form of woodfuel etc. that is used by developing countries. But if woodfuel is included in total energy consumption, one should, perhaps, also take some account of other activities outside the commercial economy when assessing total income. An alternative approach, which is useful in relation to estimates of substitution from non-commercial fuel to commercial fuels, involves measuring woodfuel by its "petroleum replacement value" (PRV), defined as the energy in the quantity of kerosine that would perform the same task. In practice the PRV is about one quarter of the thermal value of energy in woodfuel.

Our preceding discussion has been concerned mainly with a cross-section of energy consumption per unit of GNP for groups of countries at different stages of development. We have, however, noted that, using commercial energy and market exchange rates, the intensities did not change significantly over the period 1960 to 1980 for the two groups of developing countries. For the group of industrialised countries, there was a decrease of nearly 20 per cent following the 1973 energy crisis. One of the questions that we shall ask in the following sections is whether one could relate this behaviour of energy intensities to income distribution and energy demand in particular countries.

3. *Direct energy consumption in households*

Direct expenditure by families on energy arises almost entirely from household needs for cooking, lighting and heating, and the purchase of gasoline for private transport. The latter forms only a fraction of the total energy consumption in the transport sector, and this fraction will vary from country to country. However, direct energy used in households would constitute the major part of energy consumption in the domestic sector in most national energy statistics (other parts often include government's own energy use, and sometimes include the commercial sector and agriculture). In 1980, for the OECD countries taken as a group, energy use in the residential sector accounted for about 20 per cent of total final energy demand. However, for OECD Europe its share was 26 per cent, whilst for North America it was only 18 per cent. Energy statistics for developing countries are less complete than for the OECD group, but for the group of all developing countries except China, energy consumption in 1980 in the domestic sector (including residential, government, and commercial sectors) is estimated at 28 per cent of total final demand. For this estimate, I have calculated woodfuel consumption on the basis of its petroleum replacement value (PRV). On the same basis, residential energy use is probably more than 80 per cent of this share, or just over 20 per cent of total final consumption. It is, of course, difficult to separate the energy used in small-scale industry or commerce, operated at a family level, from household consumption for a family's own needs. In view of the fact that most developing countries have warm climates and little or no need for space-heating in dwellings, it may seem surprising that their household energy consumption accounts for a similar share of total final demand as in the OECD. The explanation is that their average per capita energy use in other sectors (transport, industry, and non-energy) is very low compared with that in the OECD.

For the less developed countries, the residential share of final energy demand is considerably higher than this average, for example, on a PRV basis for non-commercial fuel, residential energy use in Bangladesh in 1979 formed about 50 per cent of total final energy demand, whilst in Indonesia the share was 46 per cent (table 3.1). In more developed, or newly industrialised, countries the share of final demand taken by residential energy is much lower. Thus in 1977 in Brazil (on a PRV basis) it was 14 per cent and in 1979 in Mexico it was 12 per cent.

The foregoing shares of energy use are summarised in table 3.1, and the corresponding per capita energy consumption in the household sector is given in table 3.2. It will be observed that the relatively small fraction of total final energy used by households in Brazil and Mexico (table 3.1), compared with Indonesia, arises from the fact that

TABLE 3.1 — *Energy consumption by households compared with total final energy demand.*

	Households direct energy use [b] EJ	Total final demand [b, c] EJ	Percent share by households %
Developing countries group [a] 1980	6.4 [d]	30	21
Bangladesh 1979	0.07	0.15	50
Brazil 1977	0.39	2.7	14
Indonesia 1979	0.43	0.93	46
Mexico 1979	0.29 [d]	2.4	12
OECD group 1980	25	120	21
North America 1980	12	66	18
Japan 1980	2.4	11	22
West Europe 1980	10.4	40	26
United Kingdom 1980	1.7	5.8	29

Source: Studies in the Cambridge Energy Research Group.

Notes: [a] Excluding China and centrally planned Asia
[b] Units EJ, Exajoules. Totals include woodfuel etc. at petroleum replacement value (PRV).
[c] Total final demand excludes conversion losses and own use by energy industries.
[d] 80% of estimated use in the domestic sector.

TABLE 3.2 — *Per capita direct energy use in households.*

	Per capita direct energy use in households Electricity GJ	Fossilfuel GJ	Woodfuel PRV [a] GJ	Total per capita GJ	GNP per capita US dollars [b]
All developing countries [c] 1980	0.4	1.6	1.0	3.0	878
Bangladesh 1979	0.01	0.2	0.6	0.8	90
Brazil 1977	0.5	1.5	1.5	3.5	1360
Indonesia 1979	0.1	1.7	1.2	3.0	370
Mexico 1979	1.2	4.2	—	5.4	1640
OECD 1980	6.7	25	—	32	9842
North America 1980	12.2	35	—	47	11243
Japan 1980	3.7	16	—	20	9890
West Europe 1980	4.0	22	—	26	8848
UK 1980	5.6	24	—	30	7920

Source: Studies in the Cambridge Energy Research Group.

Notes: [a] Woodfuel and other traditional fuels at petroleum replacement value (PRV).
[b] At market exchange rates in year indicated.
[c] Excluding China.

average household consumption is similar for all three countries (table 3.2), though per capita income and energy demand is much higher in Brazil and Mexico than in Indonesia.

4. *Direct and indirect energy consumption by households*

The important studies by Herendeen and Tanaka [1] and by Herendeen [2], on the total energy cost of household consumption in the United States and Norway, distinguish between direct purchases of energy, as fuel for household use or personal transport, and indirect energy costs that arise through the purchase of goods and services.

For the United States in 1967, they find that direct fuel and electricity (including conversion losses) used by households amounted to about 25 per cent of total primary energy demand. Fuel for cars took about 20 per cent, of which two thirds was direct use for private transport, and one third was indirect. Other indirect energy use accounted for about 30 per cent of total energy demand. The residual of about 25 per cent was attributed to direct and indirect use by government and to energy used to manufacture exports.

In the following discussion, which is based on much less detailed work than that of Herendeen and Tanaka, I shall assume that energy needs for exports are approximately balanced by the implicit energy costs of imports, so I shall ignore the export-import component. When referring to final energy demand I shall omit conversion losses from the direct energy attributed to electricity, and in all cases I shall interpret woodfuel and charcoal through PRV, their petroleum replacement value. These conventions differ from those used by Behrens [3] in his study of direct and indirect energy use by households in Brazil, though his work does include estimates of the useful energy in direct use by households. Thus, my results for Brazil which are, in part, derived from those of Behrens give a considerably lower weighting to the energy in woodfuel, which results in a more rapid growth with income of household energy demand, since families with low incomes use a higher proportion of woodfuel than those with high incomes. My other main departure from the results of Behrens arises from a scaling or normalising procedure which I have used to bring the results into line with the Brazil energy balance table for 1977, using the format in Eden and Jannuzzi [5]. Apart from changing to a different year (Behrens' results are for 1975), the scaling procedure enables me to include all of the estimated indirect energy used in Brazil rather than the (major) subset analysed by Behrens. The penalty is that I have had to make an estimate for indirect energy use by government in Brazil, which may be as inaccurate as plus or minus 50 per cent. (One of the main difficulties arises in estimating the energy content of the Brazilian government's capital investment programme; a similar problem was considered in more detail for Norway by Herendeen [2]. This uncertainty could imply a possible error band of plus or minus 20 per cent in the values quoted later for household indirect energy in Brazil. This is probably similar in magnitude to uncertainties arising from other causes, such as the need to use input-output tables from an earlier year than that for which survey data is available, and difficulties about estimating average energy prices in an economy with high rates of inflation.

In table 4.1 I have indicated the breakdown of energy consumption in the United Kingdom in 1980 into the direct use of energy by households and government, and indirect energy use, which has been derived from the energy balance tables as a residual of total final demand. The direct use of energy by households is derived from the national energy balance tables "household" sector, which were reasonably consistent with the survey data [6] used for some results given later in table 5.1. The latter were used to separate the direct energy used by private cars from the total energy used in the transport sector. Similar information for Brazil in 1977 is displayed in table 4.2. This is based mainly on the national energy balance tables for that year, for which the total population was 113 million, of whom about 60 per cent form the urban group and 40 per cent the rural group.

It can be seen from table 4.1 that direct energy use by households (including private transport) in the UK accounted for 39 per cent of final energy demand. If energy conversion losses are added pro rata (using Herendeen's convention), the direct share of total primary energy is of

TABLE 4.1 — *UK: household and other energy consumption.*

UK 1980 Sector of use	Electricity PJ	Fossil fuel PJ	Total PJ
Direct energy use			
Households	310	1355	1665
Private cars	—	574	574
Government	57	317	374
Government transport [b]	—	150	150
Indirect energy use			
Households and Government [c]	440	2580	3020
Total final demand	807	4976	5783
Energy sector use and losses	−807	3876	3069
Total primary energy	—	8852	8852

Notes: [a] Source, UK energy balance tables and survey data [6].
[b] Author's illustrative estimate.
[c] Residual of final demand.

TABLE 4.2 — *Brazil: household and other energy consumption* 1977.

Brazil 1977 Sector of use	Electricity PJ	Fossil fuel PJ	Woodfuel PRV [a] PJ	Total PJ
Direct energy use [b]				
Households				
Urban	59	142	41	242
Rural	1	21	127	149
Private cars				
Urban	—	306	—	306
Rural	—	37	—	37
Government	26	24	—	50
Government transport	—	200 [c]	—	200 [c]
Indirect energy use [b]				
Households				
Urban	110	649	71	830
Rural	25	209	36	270
Government [c]	303	502	57	641
Total final demand	303	2090	332	2725
Energy sector use				
and losses [d]	25	298	—	323
Total final primary energy	328	2388	332	3048

Notes: [a] PRV petroleum replacement values.
[b] Source - based on Behrens [3] and Eden and Jannuzzi [5].
[c] Author's illustrative estimate.
[d] Hydropower input has been equated to hydroelectricity output.

similar magnitude. The corresponding figure for Brazil from table 4.2 is 27 per cent. Our earlier discussion indicated that proportionately more energy is used by households in less developed countries. This is consistent with these results if we subtract from the UK figure the 70 per cent of household energy used for hot water and space heating, which leaves residual direct use (excluding private transport) at 19 per cent of total final demand.

5. *Family income distribution and energy demand*

The direct consumption of energy in 1980 by UK households in different income groups is displayed in table 5.1. This shows that average expenditure on energy for household needs (cooking, heating, lighting, etc.) decreases as a proportion of total expenditure, from 11 per cent for the lowest income group to 4 per cent for the highest (line 4). Conversely, expenditure on gasoline for private transport increases from less than 1 per cent to more than 4 per cent (line 8), so that the total share of expenditure on direct energy use shows only a slow decline with increasing income, from 12 per cent to 9 per cent (line 10).

These figures conceal the wide diversity in energy use within families in the same income group, arising from different housing, or from differing life-styles, or from a combination of these. This dispersion is a subject which I would recommend for further study, since average figures, such as those used in this presentation, are likely to conceal or understate the more serious difficulties in meeting energy costs, that arise from those who use more than an average amount of energy relative to their income.

The direct use of energy in UK households (table 5.1, line 7) shows very little increase between the second lowest income group and the highest. Within these four income groups, the average household uses about 84 GJ per annum, the range being 75 to 98 GJ, which is probably much less than the variation within each group. There is a similarly slow increase with income, of electricity consumption. This can probably be attributed to the low capital cost of portable electric heaters which are more likely to be used at lower income levels, where central heating is less available than for higher income groups. However, the average in each group of the use of gasoline for private transport increases rapidly with income (table 5.1, line 9), from 11 per cent for the second lowest group to 53 per cent for the highest. Thus, on average, an increase of total expenditure by a factor of 2.6 (line 3) corresponds to an increase by a factor of 4.6 in gasoline consumption.

Some corresponding results in 1977 for the direct use of energy by households in Brazil, as a function of family income, are given in tables 5.2 and 5.3. The average GNP per capita in Brazil in that year was about one fifth of that in the UK for 1980, using market exchange rates, or nearly one half, using purchasing power parities. For urban households in Brazil, average income is about twice that of rural households but costs would be different and purchasing power parity adjustments would be smaller. The average size of households in Brazil is about twice that in the UK. Thus, for urban households in Brazil, the average family income is about one half of that in the UK.

The results displayed in table 5. 2 for Brazil show that the direct consumption of electricity by urban households increases rapidly with income, though there is a much slower increase in the direct use of fossil fuel and woodfuel. However, the use of gasoline (and alcohol) for private transport increases even more rapidly than the use of electricity, and the gsaoline consumption by households in the top income group is twice that of the highest group in the UK. Almost all of the direct use of gasoline by urban households in Brazil arises from the top two income groups, which contain nearly half of the urban population, though there is a smiilar amount of energy used for public passenger transport. The same two groups use nearly 80 per cent of the direct electricity consumption.

TABLE 5.1 — *UK households' direct energy use and income distribution.*

	United Kingdom households 1980					
1. Weekly income range	0/50	50/100	100/150	150/200	200+	Average
2. Percent of total	16	20	21	19	24	—
3. Average expenditure £ pa	2000	3694	5417	6632	9638	4890
4. Percent share used for household energy	11	8	6	5	4	5.6
5. Electricity used GJ pa	10	14	15	17	17	15
6. Fossil fuel GJ pa	47	61	68	67	82	66
7. Total energy GJ pa	57	75	83	84	98	80
8. Percent share of expenditure used for gasoline	0.8	2.4	2.1	4.4	4.3	3.3
9. Gasoline used GJ pa	2	11	26	38	53	28
10. Percent share of expenditure on direct energy use	12	10	8	9	9	9
11. Total direct energy per household GJ pa	59	87	109	122	151	108

Source: Survey data [5].

TABLE 5.2 — *Brazil urban households' energy use and income distribution.*

	Brazil urban households 1977				
1. Income classification	0/2	2/5	5/10	10+	Average
2. Percent of total	18	37	25	20	—
Direct energy used GJ per household					
3. Electricity	0.6	2.6	6.5	10.9	4.9
4. Fossil fuel	5	10	15	19	12
5. Woodfuel PRV	5	4	3	2	3.4
6. Gasoline	0	1	16	104	26
7. Total direct	10	17	40	135	46
Indirect energy used GJ per household					
8. Electricity	2	5	10	22	9
9. Fossil fuel	14	35	75	99	54
10. Woodfuel PRV	2	4	7	12	6
11. Total indirect	18	44	92	133	69
12. Direct plus indirect GJ per household	28	61	132	268	115

Source: Behrens [3] scaled to table 4.2.

Amongst rural households (table 5.3) the proportion of families in the higher two income groups (12 per cent) is considerably less than for urban households (45 per cent). Overall electricity consumption is very low, and more than 60 per cent of the total is used by the 12 per cent of households in the upper two income groups. These two groups also account for 99 per cent of the total gasoline (and alcohol) used for private transport in rural areas. However, public passenger transport in rural areas, used mainly by the two lower income groups, accounts for a similar quantity of energy use [3].

Indirect energy consumption arising from the purchase of goods and services by households is more closely related to total income than is found for direct energy use (tables 5.2 and 5.3). This indicates that the energy content per unit value of goods and services purchased does not change very much from the average purchases by the lower income groups to those of the higher groups. This feature is evident also from household survey data on expenditure in the UK [6]. However, I have some reservations about the translation of this expenditure data, by means of input-output tables, to indirect energy requirements, since these tables do not take account of the relation within a manufacturing sector of quality and cost. Higher quality goods, such as clothing or consumer durables, are likely to increase in value proportionately to a greater extent than does the energy needed for their manufacture. Thus the purchase by higher income groups that relate to higher quality goods is likely to reflect a lower energy content relative to their value than cheaper goods used for the same purpose.

TABLE 5.3 — *Brazil rural households' energy use and income distribution.*

	Brazil rural households 1977				
1. Income classification	0/2	2/5	5/10	10+	Average
2. Percent of total	56	32	9	3	—
Direct energy used GJ per household					
3. Electricity	—	0.15	0.6	1.3	0.15
4. Fossil fuel	2	4	4	5	3.0
5. Woodfuel PRV	14	25	23	8	18
6. Gasoline	0.5	1.2	18	83	5
7. Total direct	16	30	46	90	26
Indirect energy used GJ per household					
8. Electricity	2	5	10	8	3.6
9. Fossil fuel	15	36	67	112	29
10. Woodfuel PRV	2	7	10	17	5
11. Total indirect	19	48	87	137	38
12. Direct plus indirect GJ per household	35	78	133	227	64

Source: Behrens [3] scaled to table 4.2.

6. *Conclusions and policy implications*

As with most reviews of analytical work dependent on energy data, the most obvious conclusion is that more work needs to be done in relation to family expenditure and energy demand. In the absence of a reliable and up-to-date input-output table it would be possible to obtain useful results on indirect energy requirements arising from the purchase of goods by using results from process analysis of their energy content. This approach could be used for energy intensive goods and combined with the use of average energy intensities of expenditure on less intensive goods. As a first approximation, results from process analysis for energy intensive goods could be transferred from other countries, and their validity could be checked in broad terms by direct energy consumption in industrial sectors, such as iron and steel, or cement production.

Results on the direct energy purchases by households in Brazil show a change in the type or quality of energy purchased as income rises. Using petroleum replacement values (PRV) for woodfuel, the total, excluding gasoline, increases much more slowly than income. This tendency towards saturation of demand is shown more decisively in the United Kingdom, where the saturation effects extend also to space and water heating.

In Brazil the change in quality of fuel use corresponds to a shift from woodfuel to fossil fuel (mainly LPG) and an increasing use of electricity as income rises. A change of quality occurs also in the UK, but of a different type. As income rises, a higher proportion of households live in dwellings with central heating and better insulation; thus higher incomes lead both to the use of lower cost fuels (gas instead of electricity) and to their more efficient use.

In contrast to direct energy use in households, the use of gasoline (and alcohol) for private transport is almost zero for lower income groups in Brazil, but increases very rapidly with rising income for the higher income groups. Although some gasoline is used by all income groups in the UK there is a steady growth in consumption as income rises, reflecting both an increase in car ownership and the use of larger cars.

Indirect energy requirements, arising through the purchase of goods and services and the energy needed for their manufacture and provision, appear to be approximately proportional to household expenditure. The results of Behrens [3] for Brazil are in line with the earlier unpublished results of Goldemberg [8], and the results of Herendeen and Tanaka for the United States [1] and Norway [2]. It would, however, be useful if further work could be carried out using process analysis to investigate the relation between improved quality and higher value of particular types of goods and the energy needed to manufacture them.

These results underline the importance that is attached to the quality of fuels and energy directly purchased by households as their income rises. The limiting factor may often be the capital costs involved, whether for cooking equipment to use LPG in Brazil, or central heating and better housing in the UK, or motorcycles or cars in both countries. For electricity use in poorer countries, the capital cost of equipment is also likely to be an important constraint, but in rural areas of Brazil the absence of mains electricity is, of course, the dominant factor.

Behrens [3] has pointed to the importance of rural-urban migration in relation to energy demand. His results confirm the impact that this has on fuel choice. In towns the cost of woodfuel is generally higher and the cost of LPG lower, than in rural areas. Thus rural-urban migration leads to a major shift in demand from woodfuel to fossil fuel consumption. Conversely, the rate of inter-fuel substitution would be slower if rural development was able to slow down the migration to towns.

The direct use of energy in households in Brazil is only about one seventh part of total energy consumption. In 1977 the use of energy for private cars was slightly less than in households, but it has been increasing more rapidly, and even in 1977 it was a more important component of fossil fuel consumption than fossil fuel used in households.

If energy for public transport of passengers is included in indirect energy, the total indirect energy use in Brazil is estimated to be about 50 per cent larger than the total direct use. Together, the direct and indirect energy attributed to households amounts to about two-thirds of Brazil's energy consumption, the remainder being attributed to use by government, including both direct and indirect use and energy needs through capital investment. Although this estimate of government energy use is very approximate, there is little doubt that it is a large slice of national energy demand. This underlines the importance that should be attached by government to improving the efficiency of its own energy use, both in direct use where the price incentive for economy may be less effective than for private consumers, and through its indirect energy use through government purchases and contracts.

The changing characteristics of energy use as household income rises show that increased energy use reflects an improved standard of living, and that this involves also the greater use of quality fuels such as electricity and LPG. We have noted also that improved quality in goods and services may not necessarily mean a proportionate increase in energy use. Thus, although quantities of goods and services required will increase with rising incomes, the resulting growth over time in energy demand may be moderated by improved efficiencies in the production of goods, and by improved quality and value of goods and services relative to the energy used in their provision.

REFERENCES

[1] HERENDEEN R. and TANAKA J., *Energy cost of living.* « Energy », *1*, 165 (1976).

[2] HERENDEEN R., *Total energy cost of household consumption in Norway, 1973.* «Energy», *3*, 615 (1978).

[3] BEHRENS A., *The potential impact of income redistribution and rural-urban migrations in Brazil.* University of Cambridge Ph. D. thesis (1983).

[4] World Bank Development Reports 1982, 1983, World Bank, Washington, D.C.

[5] EDEN R.J. and JANNUZZI G., *Brazil, the energy outlook.* Discussion Paper EDP 10, Cambridge Energy Research Group (1981).

[6] *Household expenditure on fuels 1980* (unpublished survey information, UK Department of Energy).

[7] *UK Family Expenditure Surveys.* HMSO, London (annual).

[8] GOLDEMBERG J., Unpublished results described at a Seminar in Cambridge, circa 1979.

ENERGY FOR EDUCATION

ALFRED BOETTCHER
Kernforschungsanlage Jülich
D-57 Jülich, Postfach 1913, Germany

In industrial countries the energy problem is seen in general as an economic and quantitative one. As a consequence, renewable energies only play a secondary role, if any, in all discussions and scenarios. The situation is fundamentally different in developing countries having remote areas without any electric grid. Their situation could be improved qualitatively by having even small amounts of electrical energy at their disposal for basic needs, one of them being education.

For decades it has been known to all those involved in the problems of developing countries that, in spite of all governmental and private efforts, the gap between the techno-economic potentials of industrialized and developing countries has not closed but become broader. As the growth of technological and industrial potentials basically follows an exponential law, it is a mathematical consequence that, assuming equal scientific intelligence, the distance between groups having started this development at substantially different times must increase.

Attempts have been and are being made to improve the situation by systematic transfer of technology: implantation of technologies in DCs, transfer of equipment and so on. This can certainly be helpful locally and under special conditions, but it cannot basically improve the techno-economic potential of the developing country concerned. This is generally possible only by accelerating the development process itself, which means increasing the index of the exponential equation by accelerating the learning process through the transfer of knowledge and skill. This task will differ from country to country according to the traditions, cultural values and the environmental conditions of the group concerned.

As simple as this task may look, it can be very difficult especially in countries belonging to old cultures with strong traditions and value systems not including technological and economic development at a high priority level. In such cases it might take generations to reach a level of scientific and technological interest and individual motivation. But very remarkable efforts have been made in a few countries. I have been personally very favourably impressed by the Indian program, which I think has shown at least the direction in which to proceed. Improvement of education is possible in many ways in areas of good social and technological infrastructure, but it becomes very difficult in remote areas with a rural character. Here the most efficient and at the same time most realistic approach might be educational programs based on community television or videotechniques. Such programs, including (if needed) alphabetisation, information concerning agricultural methods and improvements, medical and hygienic advice etc. have to be made up individually according to the psychological peculiarities of the people aimed at.

In addition to this, the technical problems to be solved are also substantial. Television programs need television stations and receivers, video programs need recorders and the distribution of video tapes. One important part of both methods is the electric energy needed for the receiver or recorder. This is certainly no problem in areas connected to an electric grid. This does however not exist in large parts of DCs where the need for education is high. Fortunately, the amounts of electric energy needed are small: assuming that the television set has a load of 30-50 watts and the electric bulb for the community room of 50 watts, the energy for a daily two-hour program would be around 0.2 kwh/d. Only half of this is required if electric lighting is not needed. For such small amounts of electric power, solar and wind energy systems are one possible solution.

In climates with sufficient insolation the necessary electric energy can be produced by photovoltaic cells and stored for the evening hours in batteries. In order to avoid expensive electronic peripheries direct current has to be used for the television or video techniques. The costs of such photovoltaic equipment might he about twice the amount needed for the television or video recorder.

In areas of favourable wind speeds the use of wind energy converters with direct current generators might be more advantageous economically and from the maintenance aspect. In general, hatteries might be advisable in this case, too. It must he realized, however, that they are always a vulnerahle part of the system, as they need reliable minimum maintenance to reach the economically necessary minimum lifetime.

This problem would not exist in the case of two principally possible, but not yet proven, simple solutions:

— The traditional method of pumping water with animal power (oxen or camels) could be modified in such a way that the animal drives an electric generator via a gear transmission producing in this way the needed power of about 0.1 kw during the operating hours of the television set. The voltage stability as far as needed by the television or video recorder would be no major problem, the cost most probably being of the same order of magnitude as in the two cases described above.

— Another simple way would be pumping water from the ground into an elevated tank in daytime out of which it would flow during the working hours of the television set through a micro-turbine with integrated generator back to the original ground level. The energy needed to pump the water to the high level tank could be animal-, photovoltaic- or wind-energy. This way would be identical with a micropump power station, but it might most probably be more expensive than the other solutions.

In order to realize one or the other of these methods different preparatory activities would be necessary:

— The production of electric energy out of photovoltaic cells, battery storage and use for a community television set is state of the art and has been proven successfully.

— Wind energy converters of the small capacity needed for this purpose have been used in large numbers for water pumping. They can be produced in many developing countries. Their coupling with direct current generators is no problem in principle but must be optimised.

— A gear for an animal driven generator and electronic voltage stabilisation has to be developed. This would certainly be easily possible in industrial countries having broad experience in this field. It is self-evident that from the very beginning of such a development program the interested DC must be closely involved.

An important part of every educational program will always be the transfer and promotion of mechanical skill. For this purpose even in the beginning of the educational program the installation of small workshops is necessary, which in general will need a minimum of electric energy (0.1-1.0 kw) for running motors. In planning an educational program for communities it therefore seems advisable to prepare for the later increase in electric power demand for a training workshop. For this additional amount of power, storage would be helpful but not necessary.

As the need for substantial efforts concerning education in remote areas is a very general one in DCs, programs in this field should be strongly promoted on a supranational level. The development of the different methods for producing electric power should be a cooperative effort in the interest of all DCs. The preparation of educational programs and their diffusion would have to be done on a national level, — advisory assistance through experts nominated by UN organisations could be helpful. In addition, cultural and religious organisations could give very valuable assistance.

DISCUSSION

SMITH

Dr. Eden, can you please explain how you calculate the petroleum replacement values.

A second remark. Dr. Goldemberg showed in his paper an increasing use of wood with increasing income, but your figures seem to show the opposite: a decreasing use of wood use with increasing income.

Fianlly, you made the distinction between direct and indirect energy at different income levels. I think there is an important implication in that. Basically that it is much more difficult to gain control over direct energy use. The decisions about indirect energy use are made in the intermediate sectors of an economy, and there the decisions are pretty much based on economic considerations as far as people know them, as far as they are aware of the alternatives of using energy more efficiently. However, in direct energy use, you are dealing with energy at the level life is lived. As you move to families with a lower income, you will basically find 100% of energy used directly. These families buy nothing on the local markket so there is almost no indirect energy use. Consequently, it is more difficult from a centralized position, laws, regulation and taxes, to improve efficiency, because the uses of energy are more embedded in local customs and traditions.

LANDSBERG

I would like to make one very general comment that seems to me to come out of the first two days of our session. There is a fairly general agreement that aggregates and averages are not very useful, because they conceal a lot. I would agree to that but there is a penalty you pay. You have to be aware that when you descend from the convenient but to some extent — I agree — misleading averages and aggregates to such aggregated quantities it becomes very difficult to make laws and policies; thus the necessity of trade-off.

A comment to Prof. Farinelli and Dr. Al-Homoud about photovoltaics. I used to answer the question who is best suited to performing research in the new energy sources, photovoltaics, for instance, and solar energy generally, saying that it is only fair that the industrialized countries should do most of the research. They have the equipment, they can afford it. Well, I am not so sure at this point. The reason why is that there are fashions in research. In the United States, after two or three years of great enthusiasm, photovoltaics is out of fashion. I was reminded of this when I saw the last transparency Prof. Farinelli put up. Many of the companies he showed went out of the photovoltaics business. The government decided it was not its business. The final result is that now we have neither the government nor a significant portion of industry progressing in the photovoltaics field. My conclusion is that, certainly in the developed countries, the governments ought to stay in, because business will go up and down in very particular areas which do not have a very large initial investment.

Therefore, I think that LDCs must begin R&D in photovoltaics.

A quick remark on Dr. Eden's paper. What emerges from the very large number of surveys on household consumption in the U.S.A. is that in the very low end of the range it is possible for a household to spend as much as 50% of its income on energy, including direct, indirect and transportation. It is also clear that the indirect portion is much more evenly distributed.

SUAREZ

It seems to me that a new field of research is starting and it is quite important to insist on these analyses about energy consumption and income distribution. I agree with Dr. Landsberg that this complicates the entire scenario, but unfortunately, in our countries, the problems are almost always far more difficult to solve.

In relation to the oil replacement value, it seems to me that perhaps we can try to go with all the energy sources to the useful energy level. The oil replacement value is a kind of intermediate step between final energy and useful energy.

EDEN

Dr. Smith asked how to calculate the petroleum replacement value. This is a very approximate figure which was first estimated by one of our graduate students in Malaysia. He did field work there, observing the amount of energy used for cooking and he compared this with the amount of energy used with wood fuel. He concluded that in the switching to kerosene or LPG the ratio between the thermal content and the petroleum replacement value is about three or four. This is one of the difficulties with the useful energy concept.

None of the conversion coefficients are very accurate because they differ very greatly, even with the same kind of equipment.

The point Prof. Goldemberg made, showing that there was an increase in wood fuel with income, is that if you add direct and indirect energy using wood fuel, then there is, also in my figures, an increasing use of wood fuel. I think it is direct plus indirect wood fuel use that Prof. Goldemberg has found shows an increase as income rises.

Dr. Landsberg made many interesting remarks about the misleading averages problem. If disaggregation leads one to find that a simple solution is not possible and several different policy measures are required to alleviate a particular problem or to improve a situation, then I agree with Dr. Suarez who says: « so be it ». Energy use is very complicated and if complexity is revealed more by more disaggregated work then that may be helpful. I think one should always remember, though, that one has to approach the problems from all data available and from all directions, and with some simple presentation formulate some precise and decisive idea; one can go forward with it, or one may become lost in details. I would always urge someone to use all the possible approaches which can be used to solve a particular problem before resorting to political measures.

Dr. Suarez's point of looking at different countries is a good one. Comparative work can bring additional pieces of information.

BOETTCHER

A comment on photovolatics. Photovoltaics make sense if you restrict yourself to low power, up to a few kilowatts, certainly below one kilowatt. I am reluctant to suggest that LDCs invest in photovoltaics. I think the future is in the new thin layer technology, which requires less laboratory activity but a very high technology production line. LDCs have to produce them directly.

AL-HOMOUD

Let me comment on Dr. Landsberg's remarks on photovoltaics. One should think that LDCs cannot risk the fact that developed countries are pulling out of research in photovoltaics. LDCs need incentives from the World Bank so that governments will put more money into photovoltaics and the market will have the chance to develop. Another point: the critical issue is cells: we have to get a higher conversion efficiency.

Goldemberg

I think that the point made by Dr. Landsberg is a very good one. He claims that if you go into too much detail you might lose sight of the simple aspects of the problems. Well, I disagree with him. As soon as you do studies of the type we did, and Dr. Eden described here, you realize that societies are not classless. Average analysts like ourselves are finally understanding the real world. It is no use blaming the country as a whole; it is a minor fraction of the population, although a very important one, which is causing problems with the balance of payments and all that. That is the basis for political action. Unless we recognize this, we will be able to make only superficial contributions.

Landsberg

I want to keep the record unbroken with Goldemberg and myself. We do not disagree. I was making two very simple points. As we abandon or shift to more disaggregated data, we have to know that we are complicating the policy. We should indeed create simple policies. One possibility is supplying income so people can buy what they want. Simple but hard to achieve. Distinguishing dozens of categories can lead to a very messy situation.

SOME RECENT RESEARCH AT RESOURCES FOR THE FUTURE

HANS H. LANDSBERG
RFF (Resources for the Future)
1755 Massachusetts Ave, Washington, D.C. 20036

My presentation to this assembly will be some of the findings that my colleagues at RFF and numerous experts in the developing countries associated in the undertaking have reached in the course of a five-year research project on energy and development that ended a year ago.

I shall not spend the time taking you through the entire research output.

What I would like to do here today is to select a few topics and put before you the questions our researchers asked and some of the answers they came up with, most of them, you will not be surprised, of a highly tentative nature.

One other preliminary remark. I was not directly involved in the research. Thus I fill the role of a report, and an accurate one I hope, of my colleagues' work. Above all, I must place the credit where it is due, and that is in Ms. Joy Dunkerley, a Senior Fellow at RFF, who not only developed much of the work from its very beginning and directed it to its conclusion last year, but who also allowed me to use her notes on what she believed were significant aspects of the research program. I have freely drawn on them. Nonetheless, the responsibility for what I am reporting is wholly mine.

The RFF Program and Its Setting

The RFF program was two-pronged. It set out (1) to subject a number of "prescriptions" for escaping from energy problems to on-the spot test, i.e., in communities of selected developing countries, and (2) to involve nationals in those countries in the research so that, once the program had run its course, at least a better trained and more sophisticated corps of analysts might have been created as a tangible and enduring product of the project.

Knowledge of the role of energy in developing countries is meager. Before 1973 is was scarcely a topic that scholars enthusiastically embraced. Thereafter, however, knowledge was badly needed, and when its thinness became obvious, the vacuum was filled with "plausible propositions", tested neither theoretically nor practically. A highly popular one, for example, was that the obvious and ideal source of energy for developing countries was renewable sources, above all biomass and solar energy, both plentiful and presumbaly free, especially in the warm climates in which many of the poorest developing countries are located. That this proposition neglected to count the often high cost of materials required to permit utilization of sunrays or that, with some exceptions, biomass fuel competed with demand for food, or that the rapidly rising number of inhabitants of urban centers (Mexico City, Calcutta, Cairo, etc.) were largely dependent on conventional commercial energy sources like oil and electricity — these and others facts were conveniently forgotten. Another favorite proposition was that oil demand in the developing countries would rise steeply and more than offset reductions in the growth rate of commercial energy in the rest of the world, thus perpetuating continuing increases in the demand for oil and, with it, continued upward pressure on prices. This too has turned out to be a misconception, as has the idea that conservation and substitution in the industrial world so reduce oil consumption that oil would be an attractive, low-cost fuel for the developing nations.

I mention these fashions of thought mostly to illustrate the background for what some may consider the pedestrian nature of our research. It was deliberately designed to come all the way down to the family cooking stove or irrigation pump in order to begin to get a grip on what are the variables that are important in thinking about energy in the developing countries and thus to create a bit of order and rationality. Of course, we were aware from the outset that talking about the developing countries as a group suggests that they are a homogeneous body. They are anything but that. In some respects the difference between any two developing countries can be as large as between developing and developed countries, or even larger. Still, it is possible to identify characteristics that are found in most developing countries, and contrasts among them help one above all to keep in mind that there are no nostrums or panaceas equally true and applicable everywhere.

The events of 1973 and again of 1979 did not cause the energy problem in the developing countries. Problems existed before and were merely one of many manifestations of poverty. Developing countries were not poor because they commanded insufficient quantities of energy; rather, they could not use more energy because they were poor. What the 1973 oil shock and its aggravation in 1979/80 did was to push the energy problem to a high position of what some have called "the misery agenda". Fuel bills rose, inflation accelerated, less export earnings were available to buy needed imports, growth rates fell. Matters got worse when depression in industrial nations reduced the flow of exports from developing countries. Moreover, while loans, from commercial lenders as well as from multinational or bilateral intergovernmental bodies, have helped to bridge the gap for a while, after 1979 the poor countries were so highly loaned up that debt service threatened to eat up what foreign exchange earnings were not consumed by paying for oil imports, especially as interest rates had meanwhile skyrocketed. (It is in this context, incidentally, that one can sympathize with those who looked at the sun and the trees as the key to harnessing cheap and abundant energy.)

What were the realistic remedies? Analysis is made if one divides them into two groups: one that was relevant even before 1973, and one that arose subsequently. In the first, I would place the provision of adequate energy supplies for rural areas, a very old and persistent problem; deforestation brought about by the pressure of the non-urban population to secure a minimum of fuelwood (historically, these pressures on the forest have emerged in different centuries for different reasons, including ship building, need for cropland, livestock grazing, etc.); and thirdly, supply reliability to permit escape from the ever-present threat of shortages bordering on starvation.

The line-up of the second group is quite different. There one would list increased downstream production — that is, processing — of both traditional and commercial energy supplies; substitution of other energy sources for oil; improved efficiency in the use of all energy sources; modifications in development strategy in the light of high energy prices; and a sustained promotion of exports to increase foreign exchange earnings.

RFF's research did not attempt to cover all of these topics. It selected three: increased domestic energy production; rural electrification; and improved efficiency, or, by its more popular label, conservation. This choice was the outcome of consultations with the staff of the foreign aid program of the U.S. government, that gave financial support to the undertaking, with experts from developing countries, and, last but not least, the desire to lock into topics that had frequently been poorly understood (such as the belief, for example, that being hard pressed or at the margin of survival, the developing countries lacked opportunities for conserving energy. Our research revealed that the exact opposite was true.

Increasing Domestic Supplies

My first topic then is the potential for increased domestic production; we found that of developing countries that were included in this particular analysis, well over half turned out to have proven oil and gas reserves. Most have undeveloped hydro potential, Many have coal, and the potential supplies of fuelwood, if properly managed, are quite large. In the following I shall deal only with oil, alcohol fuels, and quite briefly with fuelwood.

Oil. Despite the presence of reserves, exploratory drilling has languished in the developing countries, In 1980, drilling in the countries accounted for only 16% of worldwide exploratory drilling, down from 22% in 1970, i.e., three years before the first "oil shock". Another statistic is equally revealing. According to the World Bank, the number of exploratory wells drilled in oil-importing developing countries constituted 3.6% of the worldwide exploratory drilling in 1972 and has declined to 3.1% by 1980. Most of these few wells were drilled by individual companies in countries that were already oil producers. What, we asked, might explain this phenomenon? The explanation lies with the two actors involved, the host country, and the providers of risk capital.

As for the host country, four variables are important: geologic prospects; amount and quality of infrastructure in place; the perceived political risk; and the financial structure that faces the investor. In our judgment, geologic prospects while promising are mostly for small — and medium-sized fields. Hopes for bonanzas are unrealistic. Secondly, infrastructure was frequently deficient. Thirdly while much has been made of the political risk, it was our judgment that it was outweighed by the geological risk. Fourthly, the traditional contract structure between host country and investor, which encompasses the expectations of future rewards, is geared to large fields, not to the smaller ones that seem to be in prospect. On the size question, it must also be pointed out that small fields will generally serve only the domestic market and thus not generate exportable supplies. This reduces flexibility in management, as far as the world's large oil firms are concerned, and renders these prospects less attractive. What will change this picture we have not attempted to analyze, but it is an important research question especially as oil companies do not generally agree that size is an important criterion. Nor did we try to generalize on the motivation of the capital providers in relation to the awards offered by the host country, beyond the few observations just made, though some research on this is still in progress at RFF.

As we all know, the World Bank has assumed a growing role in mobilizing oil and gas resources in developing countries, though it has had to contend with substantial opposition on the part of the United States where the Administration strongly believes that if private oil companies have not explored for oil and gas in a given country, there must be sound reasons for such decisions and government had best stay out rather than second-guess the experts. It is my own belief that this can not be a generally valid prescription. It may be correct at times but not in every instance. International agencies can under the right circumstances be a highly productive catalyst. What we need is new "social technology" and increasing recognition that private and social benefits are not.

Alcohol Fuel. I shall not dwell at length on the next topic that we investigated, i.e., alcohol fuel. There is by now a substantial literature on the subject, especially on the experience in Brazil. At first sight, this route would seem almost illogical for a developing country. Scarcity of cropland, water, fertilizer and agricultural inputs generally seems to make it inadvisable to dedicate land to producing fuel. Similarly, using trees as a feedstock could seem to aggravate deforestation trends. Finally, our calculations suggest that, by and large, alcohol is more costly than oil, especially now that the real price of oil has been declining for over two years, and, barring new massive, sustained shocks, is likely to continue to do so, for some years at least.

The rationale for developing alcohol fuel lies elsewhere. It resides in the imperative need of the pervasive transport sector for a liquid fuel and in the need to conserve foreign exchange, even at the higher price of alcohol. In the economist's language, there may be a substantial social benefit in producing alcohol that is not properly captured in the price comparison between oil and alcohol, as shaped by market forces.

The problem, as is so often the case with new departures, is that alcohol is in no way a panacea, applicable to each and every country. In that sense, Brazil is a special rather than a prototype case. In our research, we studied Brazil and, by way of contrast, Costa Rica. Our judgment was that prospects in Brazil were far better for a variety of reasons, some of which are:

(1) greater abundance of land (though not necessarily true in every location);

(2) many of the required inputs (e.g., distillation equipment) are available from local sources, thus not straining foreign exchange issues;

(3) given Brazil's position in the world sugar market, not much could be gained from adding to production and exports; indeed, this might even depress prices and revenues.

Conditions are quite different in a country like Costa Rica, where we found that alcohol production would raise the costs of land and labor, probably even other commodity prices, given the small size of the markets. Imports too would rise, both for equipment and other inputs. Moreover, being a small sugar producer, Costa Rica has the option of raising sugar output and exports without affecting the world market price; thus the competitive aspect between sugar and alcohol is significant. Other adverse consequences would be increased seasonality of employment and the likelihood that benefits from alcohol production would in the main go to large and medium-sized landowners, a situation that could be socially quite undesirable.

I have limited my comments on alcohol fuel to matters that are helpful in explaining what factors need to be considered before one can even begin to judge whether alcohol fuel is a commendable option for a given country. It is very much a matter of detached case-by-case decisions, taking account of not only economics, but social and political factors. A recent World Bank report summarizes the situation well: "The experience of the past two years has confirmed that the economics of alcohol production are highly site-specific and that, to be successful, alcohol projects require careful integration of activities in agriculture, industry, transport, and energy. The capital costs of ethanol plants outside Brazil have turned out to be higher than anticipated and the economics of alcohol production have been directly affected by the softening of world oil prices. In certain conditions — such as landlocked countries or remote locations where a surplus of molasses is available and the cost of gasoline is high — alcohol is still an economically attractive option, but the number of developing countries where agricultural, industrial, and transport sector conditions converge to make alcohol production viable is more limited than was initially envisaged."

Rural Electrification

I next come to a topic that has both admirers and detractors, and that is that rural electrification has long been considered one of the "good things in life", and questioning its universal advantages is considered in poor taste, at best. The term brings to mind the Tennessee Valley Authority and other large public works and generally is equated with something called "modernity" in the life of the farmer. It is intriguing to recall that some sixty years ago Lenin defined communism as "Soviet power plus electricity". Obviously, the yearning for electricity has deep, non-ideological roots. No wonder that in the current energy situation it has emerged as a major factor for the developing countries. As a rough measure of its significance, the Inter-American Development Bank estimates that between 1961 and 1978 over $ 19 billion has been invested in rural electrification in Latin America, of which the Bank contributed a little over $3 billion. The World Bank lent $ 1 billion for rural electricity projects between 1976 and 1982, equal to about 10% of its lending for all electric power projects, during that period.

There are many arguments in favor and in opposition. Let me line up the most important ones:

FOR : A factor of modernity
Promotes productive decentralization
Stimulates agricultural productivity
Favors industrial ventures in rural setting
Adds to health, safety, quality of rural life.

AGAINST: May be a high cost source of energy
Suffers from low acceptance by potential community; may have prolonged small usage factor.

Effectiveness as a single agent of productivity is doubtful. To test some of the alleged pros and cons, RFF conducted studies in three countries: India, Indonesia, and Colombia, basing its findings in all three on village surveys. These conclusions emerged:

1. *Agriculture.* If one contemplates only irrigation, that is to say, power to pump water, electrification can emerge as an important factor in permitting an extension of irrigated acreage, either to grow more of the crops already grown or to widen the choice to include higher value crops. It may also lengthen the growing season. However, irrigation by itself will do little. It requires a whole set of complementary inputs, from fertilizer to marketing outlets and financial credits. Thus, even though irrigation is crucial, the effect is indirect, working through a cluster of inputs. Perhaps it is because this complementary need is often ignored and irrigation via electrification considered in isolation that our surveys found that the use of electricity for farming purposes remained low despite the prospect of increasing crop yields.

A second finding of interest was that the growth of irrigation pumpsets is a function of the year in which electricity first came to the village, and, not surprisingly, of the cost of alternative energy sources. In Indonesia, for example, substantial government subsidization of diesel oil and kerosene discouraged adoption of electricity. A factor in electricity's favor is that it is generally a more reliable supply source and that it is preferred when water is at great depth.

Rural areas are typified by low demand from a highly dispersed group of potential consumers, i.e., the exact opposite of the situation that best fits the characteristics of electricity. Generally, acceptance is highly correlated with income, but it is not at all clear which way causality runs; and it might over time run both ways, with higher income households first adopting it because they can afford it and then raising their income as they use electricity productively. Here as elsewhere the dearth of good data permitting credible analytical findings is pervasive. Our work thus constitutes both a set of tentative findings and an agenda for further research, that would include the search for organisational innovation to use electricity more efficiently.

2. *Industry.* Even more so than in the case of agriculture, electricity is only one of the many factors in the establishment and success of rural industries. Moreover, we found that generally hookup rates are

discouragingly high so that even when the grid has reached a village, the role of rural industry generally remains low. That may be less regrettable than would appear, for electricity may not in any given case be the least costly source of heat or power. On the other hand, some technologies that depend crucially on electricity may not succeed in penetrating the rural village economy at all.

3. *Household.* By far the most prevalent application of rural electricity is in households. The best figures we could come up with relate to 1971, published in 1975; they show that the share of rural population served by electricity (i.e., connected to the grid, though not necessarily using electricity) was 23% in Latin America, 15% in Asia and 4% in Sub-Saharan Africa.

The traditional perception of rural electricity has been that above all it brought light and thus greatly enhanced the quality of life after darkness had set in. This appears to be less true today. Now appliances emerge as a very important category of electricity use, and its correlation with size of area and family income is solid. In an Indian state that our research studied in detail only 8% of population centers with fewer than 500 people were electrified, but of those in the 5-9,000 population category fully 89% had a grid connection. As for the influence of income, we found that annual use rises from 90 kWh in the lowest to about 1,000 kWh in the top income group. Such figures might lead one to conclude that, from a social point of view, the introduction of electricity far from being an equalizer might well accentuate social inequities. But that simply emphasizes a point made earlier: people are not poor because they lack access to energy; causation runs in the reverse direction. Trite as the observation may be, changes in income distribution are the obvious way out of poverty. Incidentally, our surveys revealed that among household applications ironing ranked high. So did radio, fans, and refrigeration. In Colombia, 60% of grid-connected households had TV. Especially the last two represent a costly investment, not feasible at low income levels.

4. *Conclusions.* Let me conclude this brief sketch of rural electrification with three sets of comments. The first addresses what one might call indirect effects, that is, those benefits that accrue to society as a whole rather than being subject in their entirety to appropriation by the user.

In this list one would find:

(1) Social uses such as improvements in education, clean water, better hygiene, less food waste, greater interpersonal relationships through lighting;

(2) Environmental improvements, especially reduced inroads on forests for fuelwood gathering, and less use of dung, which is a valuable agricultural input;

(3) Foreign exchange savings, provided the primary energy source is domestic (e.g., hydro, coal);

(4) Political stability;

(5) Encouragement of innovation, in line with the perception of electricity as an agent of change;

(6) Possibly a slowdown of migration to cities, though the evidence is not at all conclusive. In India, in fact, the evidence we gathered was negative, possibly because the advent of electricity further raises expectations that can be fulfilled only in cities, or so goes the belief. In Colombia, on the other hand, employment opportunities seem to attract people into electrified villages.

The second issue deals with the role of electricity vs. competing forms of energy. After all, irrigation pumps can be powered by diesel oil, and rural industries can use coal, oil, or gas. There are, however, some factors peculiar to electricity that give it an advantage. Among them are: easy control and maintenance (especially as compared to diesel engines), instantaneous availability as well as shut-off, reliability, cleanliness, absence of local pollution effects (these are concentrated at the generating site). All this is important when one evaluates the role of the apparently high cost of electricity.

Indeed, the third set of issues goes precisely to the cost/benefit calculus. The information here is drawn from a 30-village survey in India. In all but one, financial cost exceeded financial benefits. Bad as this sounds, it is not unexpected because two factors — high rate of subsidization and low rate of acceptance — combine to work against profitability. What one might call the economic, or national, cost/benefit calculus is better, though not exciting. Six out of thirty show a positive result. It is only when one includes other factors (modernization, regional equity, greater food self-sufficiency, lower oil imports, and so on) that the ratio improves. Still, electricity remains an expensive option, especially in sparsely settled areas, distant from the grid.

Among the least viable applications were found to be vertical axis windmills, solar-thermal devices, and, perhaps surprisingly, photovoltaics. Somewhat better results were found in horizontal axis windmills, but, unfortunately, windmills cannot store energy and thus have limited use for powering irrigation pumps.

To the extent that policy conclusions can be drawn from these studies, the following merit thought:

(1) In the design of rural electricity facilities, stress production over social uses, and include a design for tariffs.

(2) Aim for high load and stress not just the introduction, but growth.

(3) Integrate design for agriculture, commerce, industry, and households.

(4) Stress overall rural development, that is to say, make certain of the availability of complementary inputs.

(5) Viability is highly dependent upon distance from the grid. This puts a premium on decentralized systems. Still, other factors can offset the disadvantages, such as a clustering of pumpsets, absence of gravity fed irrigation, adequacy of groundwater, and so on.

Fuelwood

Widespread official concern over fuelwood in the rural environment is of relatively recent origin. In the past the matter was left to individual initiative and was largely outside the cash economy. Continued rapid population growth, since 1973 compounded by high oil prices, has pushed fuelwood problems into prominence and concentrated attention on tree-growing, as opposed to firewood gathering. Several options have been proposed:

(1) Add a fuelwood component to traditional plantations.

(2) Encourage villagers to raise trees in their individual plot.

(3) Encourage tree-planting in communal plots for all types of wood needs, possibly aided by some form of government assistance.

Experience with different schemes now exists in a number of countries. RFF's efforts were concentrated in Tanzania and the Sudan. If one was to select the most significant findings they are that:

(1) The key element of success is wide local participation as opposed

to a "from the top down" process. The reason is that inputs (labor, etc.) must be made in the present, while the results lie substantially in the future. Thus motivation is a crucial ingredient.

(2) Another important prerequisite is a clear, generally understood, favorable legal and land tenure framework. And,

(3) Long term commitment is needed, not only for one time success, but also to encourage replication.

Conservation

The potential for energy conservation is very large in most developing countries. It sounds outrageous according to conventional wisdom, which sees the poor nations living at the edge of survival and thus unable to do with less. But that judgment misunderstands conservation, which is not "doing with less" but using whatever is used more efficiently. And here the developing countries offer a very large, unexploited potential, as is evident when one looks at per capita income and per capita energy consumption data for a large group of countries and fails to find any systematic linkage. What is of interest in the context of conservation is that there are many developing countries that have a low per capita income associated with high per capita energy consumption. One concludes that the conservation potential must be there.

What are some of the determinants of relative energy intensity? One is industry structure (some countries have large energy-intensive industries, others operate low-intensity ones). A second determinant is price policy. When energy prices are subsidized, consumption tends to be higher than one would expect at developing country income levels. Type of fuel used is another important variable.

Traditional fuels are typically used with very low efficiency. (The open fire or stove probably ranks at the lowest end of the range of effectiveness.) Coal is more efficient than, say, fuelwood or dung, but ranks below oil and gas.

While these factors go far in explaining differences in energy intensity, there are others, as becomes obvious when one finds wide differences among countries. It is not uncommon for energy consumption per unit of output to be 50% higher in developing than in developed countries. In such industries there is usually the presence of an energy-intensive technology and/or lack of capital to make investment for shifting into a more energy-efficient mode. Other factors are low capacity utilization, age of equipment, scale diseconomies. The lesson here is simply to get away from comparison of aggregates and delve into detail, especially to judge what it will take to exploit the conservation potential. Of obstacles to conservation there are many. Let me name a few:

(1) Subsidized prices (in Ecuador sugar mills burn petroleum products rather than sugar by-products. Elsewhere we found kerosene used in such a low-value activity as brick-making).

(2) Energy costs are usually a low share of total costs. Typically, no records are kept when that share falls below 5%, as it often does. Thus, lack of basic knowledge impedes improvement.

(3) There is lack of communication. Too few large firms exist to form a pool of experience between them. In fact, energy efficiency is usually found to be highest in branches of international companies.

(4) Capital availability may be inadequate.

(5) Imports of efficiency promoting equipment tend to have a low important priority.

It is obvious from this roll-call that government can have an important part in bringing about improved efficiency, be that in generating information about energy reflect costs, or through establishing mechanisms that compensate for market inefficiencies if not failures, especially in cases where providers of goods and services lack incentives to be efficient and government can step in either to create incentives (fiscal or otherwise) or to set standards.

These observations and principles are applicable over the whole range of energy using activities. Because of their reliance on liquid fuel, they are especially important in the transportation sector. Above all, it is road transport that represents a key target for efficiency improvement — not less so, indeed, than in the industrialized countries — largely because it is the one activity in which it is generally not feasible to replace liquid fuel, and that means, with few exceptions, oil. Moreover, car ownership rises rapidly with income, even in the face of rising fuel prices. This tendency subsides only at much higher income levels that are generally out of reach in the developing countries.

Opportunities for conservation in road transport in the field of technology and operation of vehicles are as numerous as they are obvious: improved engines, higher load factors, greater use of low-energy-intensive transport modes come to mind. But there is ample opportunity in the institutional field, aimed at reducing aggregate transportation demand. Specifically in urban areas the measures our research has come across are:

— Provision of employment opportunities nearer residential areas; this may be coupled with tax policies that favour appropriate shifts in land use and investments;

— Traffic restraints, These may be physical, legal, or fiscal.

— Shifts in modes have already been mentioned. Urban rail and subway services are energy efficient, but caution is advised, because they need high load factors to pay off (there is no dearth of horror stories of mass transportation systems in developed countries that depend on subsidies due to low load factors). Moreover these systems have high construction costs, long lead times and lack flexibility once laid down.

— A better bet is expanded bus service, provided routes are sensibly allocated, fares are structured to favour the poor who often live on the urban fringes, and transfers are provided to create a true network.

— Finally, both taxes and import policy can be geared to giving preferential treatment to energy efficient vehicles.

As advice is freely given by experts from the industrialized countries, one cannot suppress a certain degree of embarrassment when one thinks of the urban traffic chaos that exists in most large western cities. However, the relevant lessons may still be learned in time to channel urban transport along more efficient paths in at least some of the developing countries; for the potential surely exists. In this connection, it must be said that freight traffic is an area where it is probably too late to reverse the trend from rail to highway transport, again a development paralleling that of the developed countries. However, even here, conservation opportunities are not lacking. They include, as in all activities, higher load factors, improved efficiency of trucks, and improved freight terminals to speed loading and unloading, especially along routes of high density.

I am aware that I have only scratched the surface of the conservation potential in developing countries, but what is important is to show the breadth of that potential and to lay to rest any notion that in countries with pervasive poverty there is no room for conservation. If anything, the opposite is true. Not only are there great opportunities, but the need to stretch what little energy is used through using it more efficiently is imperative.

Let me conclude this presentation by urging a general sense of skepticism about conventional wisdom regarding the role of energy in the developing countries. Many things are not what they seem, and what appears plausible on general reasoning as often as not turns out not to be so. What is badly needed is not just more aggregate data, but careful analysis through case studies of the kind our research at RFF has been conducting. Fads and fashions are rampant in considering appropriate policies in the developing countries as they have been in the industrialized nations, and it is only slowly that a body of knowledge, based on patient data gathering and analysis, has been evolving. I am sure this conference can contribute greatly to the spread of the awareness. Thank you.

THE PRODUCTION AND USE OF ELECTRICITY, HEAT AND POWER SUFFICIENT FOR A DECENT LIFE FROM RENEWABLE SOURCES

M.W. THRING
Queen Mary College
London, U.K.

SUMMARY

PART I. *How much energy is essential for a full human life?*

The average use of energy per capita in the rich countries (where it is mainly from fossil fuel) is more than 10 times that in the poor countries (mainly from biofuels used very inefficiently for cooking).

An attempt is made to assess *the minimum quantity of energy* needed to provide the main benefits of the industrial revolution (food, hygiene, homes, lighting, transport and educational communication) to an average person in a warm country. The result (see Table I) is less than 400 kg of coal equivalent, even if all the power is obtained from heat with only 10% efficiency. This is less than the amount of energy used per head at present in the poor countries, so that the development of suitable technological equipment could certainly give these benefits to everyone in the world, using renewable fuels. No account is taken of the fuel needed to provide the initial equipment and infrastructure (e.g. roads and railways) as fossil fuels can readily supply these.

PART II. *How can this energy be produced from renewable sources?*

It is suggested that biomass will be used as a permanent source of fuel only when it is a by-product (such as straw, or timber tree branches) of other products — with the exception of land which is only suitable for forestry. Where animals are kept, biogas could supply all the heat

TABLE I - *Minimum Energy Requirements for a decent life of an individual in a rural area.*

All figures are in kCE/C.a. (kg of coal equiv./person-year)
1 kCE/ = 2.8×10^7 J or 7.8 kWh.

Requirement	*Energy Required* as power or electricity		*Thermal Energy Required*
	Provided as power	Made from heat	
	kCE(p)/ca	kCE(h)/ca	kCE(h)/ca
1. Food production a. as fertiliser b. as cultivation			52
2. Leaf fractionation	0.67	6.7	—
3. Irrigation	0.03	0.3	—
4. Refrigeration	7.5	75	—
5. a. Cooking - b. hot water c. boiled water	—	—	60
6. Lighting	1.2	12	—
7. Domestic Equipment Replacement a. clothing and houses b. imports to village	1.0	10	2 10
8. Local industry	5.0	50	20
9. Industrial Imports to village (tools, bicycles)	—	—	20
10. Personal transport	—	—	7.5
11. Goods transport	—	—	7.5
12. Communication	0.7	7.0	—
Total required for electricity or power	16.1kCE(p)	161kCE(h)	
Total required as heat			179kCE(h)

Note 1. To pay for the imports to the village it may be necessary to double the figures for food production (item 1) and/or those for local industry (item 8).

Note 2. Items 1, 9, 10 and 11 are expressed as fuel inputs because for example, it is conventional to measure diesel or petrol for transport rather than engine power.

TABLE II - *Summary of Ways of providing the Requirements in Table I from renewable energy sources.*

Source	*Can be used to supply all of:*
Biomass	
Straw/combustion	1a. 1b. 2. 3. 4. 6. 8. 10. 11. 12.
Charcoal: direct	5a. 5b. 5c.
gasified	1b. 2. 3. 4. 6. 8. 10. 11. 12.
Dung: fermented	5a. 5b. 5c. 1a.
Small Wood	5a. 5b. 5c.
Solar	
2 m^2/cap.	2. 3. 4. 5a, b, c. 6. 7a. 8. 12.
Wind	
0.2 m^2/cap.	2. 3. 4. 6. 8. 12.

for cooking. Sized charcoal made with by-product recovery from tree branches can be a suitable fuel for gas producers for transport. Biomass burnt in boilers for power production can provide heat for cooking etc. from the pass-out steam.

Less than 2 m^2 of solar collector could provide all the heat and power needed hy each person. A cheap miniature "power tower" solar concentrator giving steam and boiling water is described.

1/10th m^2 of windmill collection area could provide all the power needed by each person in an area with good winds. A standby system (e.g. biofuel/steam) would be needed for windless periods.

Steam engines, mainly compound cylinder, are being developed because the boiler can accept a very wide range of fuels, from coal to straw. They will be used in locomotives, tractors, "mechanical bullocks", electricity generation and even for lorries.

PART I. HOW MUCH ENERGY IS ESSENTIAL FOR A HUMAN LIFE?

I. *Objective of Part I.*

The industrial revolution has been based on the almost unlimited use of cheap energy, obtained almost entirely from fossil fuels, and the economic motive has therefore led us to use energy in ways which are extremely wasteful. We would certainly admit this if we had to pay 10 times as much for fossil as we do now, and as our descendants will certainly have to do.

Examples of this extravagance are:

1. Built-in obsolescence — throw-away goods and consumer goods with an unnecessarily short lifetime.

2. Cars designed to go twice as fast as the legal speed limit and carrying only the driver.

3. Continual changes of fashion.

4. Uninsulated houses requiring fuel heating in winter and air conditioning in summer.

5. The conversion of fossil fuels to electricity followed by the use of this electricity for low grade heating purposes, e.g. hot water.

6. Failure to instal fuel saving equipment in industry because it will not pay for itself in a few years because fuel is so cheap.

From the point of view of the peoples of the undeveloped countries the problem is to provide all the essentially good consequences of the industrial revolution with as little energy as possible. The resulting figure should, of course, also represent a target for the rich countries if they are concerned with the best interests of their own descendants.

In this part I shall try to find the order of magnitude of this essential minimum annual energy supply for a decent life. I do not include the energy to establish the conditions initially such as building roads and sewers, or installing windmills or solar energy systems, because it is clear that the fossil fuels can supply all this energy once for all, before they run out. This minimum energy annual consumption will of course vary considerably with climate, rainfall (annual quantity and monthly variation) and even with local customs, which should certainly be left undisturbed as much as is consistent with providing every need.

However in spite of these variations, it is necessary to estimate an order of magnitude for these essential energy needs, in order to see whether a stable world society is possible within the earth's resources. In the long run all the energy needs of our descendants in rich as well as countries which are now very poor, must be supplied from renewable resources, and we must regard the fossil fuels as a capital resource — when it is all spent

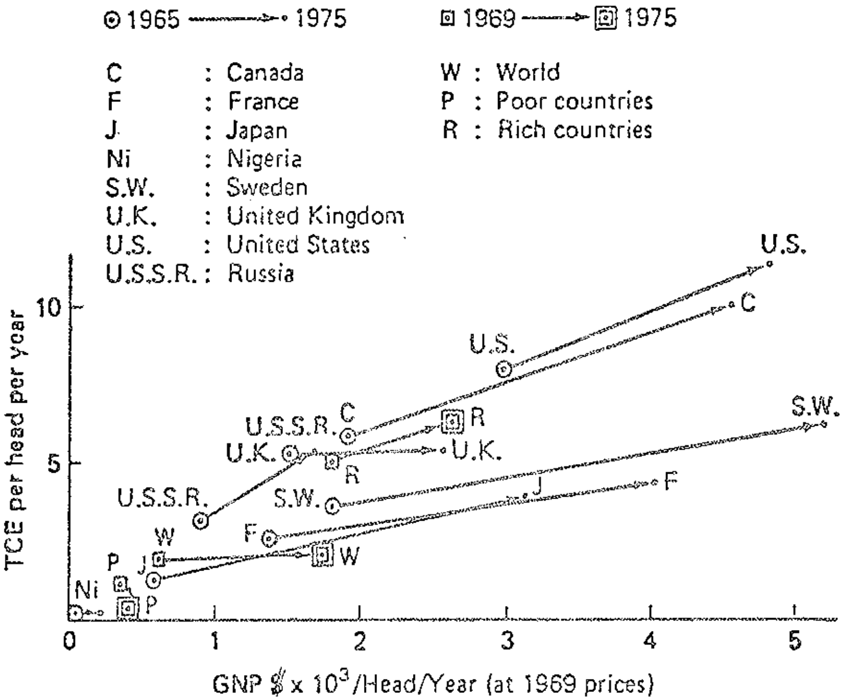


FIG. 1. Fuel consumption and GNP.

it must have provided the machinery which will enable us to obtain all the energy we need from renewable resources.

Fig. 1. (fig. 4.1, p. 61, *The Engineer's Conscience*, Thring, 1980) shows the energy usage per capita per annum in various countries in 1965 and 1975 (expressed in tons of coal equivalent — TCE) plotted against the average wealth of the individual in the country (expressed in $ GNP/c.a.). It should be noted, however, that for all countries this "wealth" includes money spent on "defence" i.e. devices for killing people and destroying their homes, which may exceed any of the useful activities like education or health.

The average energy consumption for the poor countries was less than 1/2 TCE/c.a. and went down significantly in that period, mainly because of the population increase and the exhaustion of wood fuel resources. In this period also the "Green Revolution", based as it was on oil imports, was brought to a halt by the rise in the price of oil, showing clearly how dangerous it was to rely on importing the monoculture system of western agriculture. The fuel used in these countries was almost entirely for cooking and usually this was done in stoves or open fires with an efficiency well below 20% so that more than 5 times as much fuel was being used as was essential. The average for the rich countries went up in the same period from 5 TCE/ca to 6 TCE/ca roughly in a directional parallel to the general band. The upper edge of the band corresponds to countries which use their fuel most wastefully because they had very cheap fuel in the past. The world average figure remained fairly constant at around 2 TCE/ca.

It would seem that the best way to estimate the minimum energy requirement for the achievement of a decent standard of living is to estimate the minimum primary energy input required to produce those products which are essential to a full human life. This will clearly be far below the average figure of 5-6 TCE/ca used in the rich countries because of the wasteful factors outlined above, and the problem is to estimate how far below. It is essential to take the primary energy input because if electricity is generated from heat, whether this is obtained from combustion of fossil fuels or from nuclear fission, the final energy used is rarely more than 25% of the heat input and if one takes into account the fossil fuel input for building the power station and distributing system it is considerably less. In my calculations I shall assume that if electricity or power is made in small plants from heat of combustion of biomass the conversion efficiency is only 10%, but of course passout heat at 100°C can also contain more than 50% of the fuel heat, and this can be used for other purposes. Thus over 60% of the calorific value is finally usable, even in a very small plant.

As a unit of convenient size I shall use 1 kg of coal equivalent, called KCE and take this as equal to 7.8 kWh or 2.8×10^7 J or 28 MJ.

II. *The Energy needed to supply a full diet.*

The energy in the food a well fed person needs is 2500 kcal/day i.e. 10.5 MJ/day or 3800 MJ/a; this is equivalent to 140 KCE/a or a continuous electricity supply of 120 W day and night. Of this diet some 38 kg/a of protein is necessary and if this protein comes from less well balanced sources such as seeds then 57 kg/a is necessary. Wheat has rather more than half the calorific value of coal (17 MJ/kg) so the full diet can be provided by about 210 kg of wheat/ca.

The problem is to determine the minimum energy input (excluding sunshine directly falling on the field) required to grow and cook this food. We must assume that it can no longer be grown purely by human manual labour with natural rainfall and fertilizers because the growth of world population necessitates, in most areas of the world, a much higher production per hectare than can be produced by these primitive means. However, it is also true that in the developed countries we can grow far more cereals than we need for our own food or even for the very inefficient conversion via animals, birds or farmed fish to human food. "Animals seldom return as much as a tenth of what they eat" as human food (Pirie: *Food Resources*, Penguin, London, 1976).

In Britain in 1968 (quoted from "The Engineer's Conscience" based on various sources, esp. G. Leach: *Energy in Food Production*, 1975):

1. The primary plant material grown on the farms contained 2½ times as much energy as the fossil fuels used to grow the crops. This fossil fuel input to farms is distributed as follows:

Buildings and Services	19%
Machinery	12%
Fertilisers	30%
Fuels and power	39%

(In Canada, fertilisers take 46% and 57% for cereals and maize, respectively, of the farm gate energy).

2. Since most of the crops are used to feed animals, the energy in the crops leaving the farm is about 1/10th of the energy in the crops grown.

3. The energy in the fossil fuels used to produce human food via animals is about 3 times the energy in the food.

4. Food processing, distribution, packaging and selling use more than twice as much fossil fuel energy as is used on the farms.

5. The total energy in all home grown foods (which was 57% of our requirements) is just over 10% of the total fossil fuel energy used to produce and process all our food (i.e. including that used to produce our imported food).

6. The fossil fuel energy consumed in western style sea fishing is about 20 times the energy of the fishes eaten and this figure is rising steadily as fish stocks are depleted.

To produce 1 kg of butter requires nearly 4 times as much fossil fuel as to produce 1 kg of margarine from soya beans, even though these are imported from the USA to Denmark. Both margarine and butter require 6½ times as much energy as sugar for packing, transport and retailing, because of the requirement of energy for refrigeration, although sugar requires considerable energy for evaporation unless multiple effect evaporation is used.

In the USA and Canada the total energy usage for food production alone is 1400 KCE/ca which is about 4 times the per capita energy use in Asia *for all purposes.* Thus if all the world used as much fossil fuel for food per capita as N. America 2/3 of the total world energy use in 1970 would have been consumed purely for food production.

While conditions vary enormously from region to region and so do eating habits, these figures do enable us to make an estimate of the energy requirements (other than that of the sunshine directly absorbed by the crop) to give even the poorest people in the world a fully adequate diet. We must assume that animals will be used to produce food only where they live either on by-products of human food crops (such as barley straw or rice hulls) or on marshland or hill country that cannot be made useful for human plant crops of any kind; and that the human protein requirements will be supplied mainly from legumes (beans, peas etc.) or from high protein cereals (e.g. wheat has 10-12% protein so that sufficient calories in the form of wheat also supply sufficient protein). Unfortunately this is not true in the case of rice, or from the leaf fractionation process developed by N.W. Pirie. Where the protein comes from fish we must assume that all fishing is by the traditional low energy methods (sailing or rowing boats) and that fishing does not proceed to an extent that it depletes stocks.

Thus an average diet to be fully adequate (10 MJ/day and 38 kg protein/a) would be provided by:

1. 210 kg/ca of wheat.

or 2. 200 kg/ca of rice + 38 kg/ca of animal or leaf fractionation protein.

or 3. 200 kg/ca of rice + 57 kg/ca of seed protein.

There are many countries where this provision requires a doubling of present yields per hectare and others where it requires also an increase in the amount of land used to grow food for local consumption. They also require a substantial reduction in the loss of food due to rodents, insects and rotting.

A reasonable estimate of the energy needed to give this amount of food is that it is the same as that used to produce the primary plant material on the farm in Britain, i.e. 40% of the energy in the food crops. This gives a figure of 4 MJ/day or 52 KCE/c.a. This is Item 1 of Table I.

It should be noted that if wheat is the food crop the energy content of the wheat straw is about half that of the wheat, viz. 5 MJ/day or 65 KCE/ca. Thus the straw could provide all the energy needed to grow the crop if it could be used with the same efficiency as the fossil fuel is used in Britain. In particular in regard to the artificially fixed nitrogen needed (30% of the total) the straw from 1/3 of the land could fix all the nitrogen. It would of course be necessary to have a farmers' cooperative central plant using the straw from a radius of up to 20 km in order to have a plant of reasonable size — this is discussed in a separate paper.

If we assume that people in a village require a protein supplement by leaf fractionation of 10 kg/c.a. i.e. 1/4 of their total protein intake then the energy requirement per person will be about 5 kWh/c.a., i.e., 0.67 KCE/c.a.

We can also assume that some energy will be needed for pumping water to grow the food in some areas. Theoretically 1 kWh will raise 122 T of water by 3 m and so 1 KCE (power) will raise 950 T of water by 3 m. Thus if every person needs 15 tons of water pumped every year, we require only 0.015 KCE(p)/ca or if we assume a pumping efficiency of 50% we need 0.03 KCE(p)/ca. This would provide 25 mm of water 3 times a year over an area of 200 m^2 or 0.02 ha which can grow 100 kg of wheat. This is only one half the amount needed per person and much more irrigation than this will be needed in some areas; however, it may be a fair average for all areas.

The animal-operated pumps used in poor countries have a very low efficiency when one takes the energy in the animals' food as the input. Pirie (*Food Resources*, 1976, p. 49) says that the area needed to feed the animal may be half the total irrigated. If a windmill and piston pump is used the efficiency is very much higher and no land use is wasted. Even a solar operated pump needs only a small fraction of the land area and the collector can be over non-agricultural land.

For food preservation we can assume that each family of 4 people requires a compartment in a communal fridge needing 25 W continuous or 219 kWh/fam.a. or 7.5 KCE(p)/ca. If this energy is obtained from biomass with a conversion efficiency of 10% then 75 KCE(h)/ca is needed.

III. *Cooking and water heating.*

In theory, with perfect insulation, the energy for cooking food is only that needed to bring the food up to the required temperature: the hay box cooker could approximate this, but only for food that would continue to cook at temperatures well below 100°C. In practice a reasonable estimate can perhaps be obtained for a well designed efficient cooker, if we suppose that the energy required is 4x the heating energy to allow for heat transfer inefficiency and heat losses during temperature maintenance.

Thus if we suppose that boiling rice requires a weight of water equal to that of the rice, we obtain an annual energy requirement per person of: $- 400 \times 80 \times 4.2 \times 4$ kJ = 540 MJ/ca or 20 KCE/ca.

To allow for hot water for washing and hygiene this figure might perhaps be doubled. i.e. add another 20 KCE/ca.

In many cases it will also be necessary to bring all drinking water to the boil for disease prevention; say 2 litre/day with an efficiency of 50%, this would require:

$$2 \times 80 \times 4.2 \times 365 \times 2 \text{ kJ/ca} - 490 \text{ MJ/ca} = 20 \text{ KCE/ca.}$$

This figure could be halved by having a simple heat exchanger, as the water is needed cold, but I assume this is not available.

Thus we arrive at a total energy requirement to satisfy these three domestic needs of only *60 KCE/ca.* Prof. Hall (*Humanité et Energie*, 1981, p. 411) estimates that the average rural person in a developing country uses about 15 GJ/ca (= 540 KCE/ca or 1 ton of air dried wood) of biomass derived energy every year mostly for cooking. Thus the actual use is some 9 times the theoretical energy for cooking and water heating even after allowing generous margins for inefficiency. Since this overuse of biomass is causing real damage, both to the environment and to the lives of many people, it is clear that the more efficient use of biomass and the use of solar energy more directly for cooking and water heating requires widespread research and development.

IV. *Space Heating, Domestic lighting and other domestic needs.*

It does not seem to be necessary to allow any figure for space heating, as most of the poeple whose needs are greatest live in areas where the sun provides sufficient heat during the day, which can be retained in the building for any night-time heat needed. Similarly, traditional methods can be used in many cases to render summer cooling unnecessary.

For comparison, in Britain some 86 MTCE/a or 1.56 TCE/ca (i.e. 1560 KCE/ca) is used in homes, offices and shops, of which 56% (880 KCE/ca) is used for space heating, 12% for water heating (190 KCE/ca) and 4% (62 KCE/ca) for cooking. The space heating usage is so high because in our cool winters we have been able to heat our buildings very extravagantly with very large supplies of cheap coal, with scant regard for our descendants.

However it would seem that some domestic lighting is an essential need for a proper life. A single battery torch with fluorescent bulb has been developed in rich countries which will give light for a whole room on 5 W, and so we can assume a 20 W system for each family of 4 people operated for 5 hours every night of the year, i.e., 36 kWh/fam.a. or 1.2 KCE/ca. This must be supplied as electricity so it is 1.2 KCE(p)/ca and would need 12 KCE(h)/ca if supplied by combustion of biomass.

As far as housing is concerned we could assume that each person needs 1 T of timber every 50 years, i.e., 20 kg of wood or 10 KCE(H)/ca; clothing can be estimated at materials (biomass) of 4 kg/ca, i.e., 2 KCE(p)/ca together with power of 1 KCE(p)/ca.

V. *Small local industry and imports of tools etc. from towns.*

In a small rural area of 1000 people there should be several small factories manufacturing as much as possible of the equipment, tools and food handling needed for the life of the area and too elaborate for individual farmers or housewives to make. If we assume that they employ a total of 100 people, whose physical work is equivalent to 10 kW, they might need 20 kW of power to assist them for 2000 hrs a year. This 40,000 kWh/a is equal to 1.4×10^{11} J/a or 5000 KCE(p)/a; this gives 5 KCE(p)/ca for the needs of each person. If made from biomass it would need 50 KCE(h)/ca. If they also need a small forge or other heating equipment we can allow 20 KCE(h)/ca for this.

A measure of the energy needed for the goods that require to be made in large central factories can be obtained by estimating the annual steel requirement of the villagers. In western countries, especially in time of war, we have used figures up to 1 T of steel/ca but even in peacetime, when we use 1/4-1/2 T/ca we could have everything that really matters for less than 1/10th of this figure, if we were to make consumer goods last a lifetime. In a village with real economy we can assume that 10 kg/ca of steel will be needed to replace hand tools and repair agricultural machines and supply bicycles which would last 20-30 years. This would require 20 KCE(h)/ca.

VI. *Transport and Communication.*

It has long been recognised that people in western countries would be much healthier if they used bicycles instead of cars for all short distance travel. The human powered bicycle is by far the most efficient way of passenger transport, closely followed by the bicycle with electric power assisting. The pedal tricycle and rickshaw is widely used for goods and passenger carriage in many countries. Filled buses and light-weight trains can also give 200-400 passenger miles per US gallon of petrol (1.3×10^8 J or 5 KCE(h)) while the best use of cars (small car with 4 passengers) gives only 100 passenger miles per US gallon. (see Chap. 3.3, *Energy and the Car* by G. Leach, in « Energy and Humanity », P. Peregrinus, 1974).

We can, therefore, estimate the minimum transport needs for personal travel, assuming that all neighbourhood journeys are made by bicycle but that each person makes one 50-mile journey/month by minibus or train. This requires $600/400 \times 5.0$ KCE/ca = 7.5 KCE(h)/ca.

To allow for goods transport (e.g. agricultural products from the village to the town and manufactured goods from central factories from town to village) we can add an equal figure of 7.5 KCE(h)/ca.

As far as communication is concerned a reasonable assumption would be that a village of 1000 people would need 10 TV sets, of 100 W each, which would be in use in schools, for teaching children by day and for use by families in the evening. This would require 1.0 kW for 5000 hrs a year or 5000 kWh/a = 5 KWh/ca = 0.65 KCE(p)/ca. If the electricity is made from biomass it would need 6.5 KCE(h)/ca.

VII. *Conclusion.*

Table I summarizes the various estimates. While these are very rough, estimates only of orders of magnitude, it does show some very interesting results.

7.1 The totals can be compared with the total use of 5000-6000 KCE/ca used in western countries, and nearly twice as much in N. America. This shows the enormous gap between our lavish use of energy and the quantity that would suffice if we had developed our technology without an abundant supply of cheap fossil fuel. Some of the methods by which we squander the earth's limited store of fossil fuel may be listed as follows:

(1) Some 30 or 40% of the energy we use is spent on preparations for war. Some other uses such as space rockets and nuclear studies would never have become large users of fuel if there had not been a close connection with war purposes.

(2) Often we convert fossil fuels to electricity and then use the electricity for space or water heating.

(3) We do not spend capital on known fuel economy measures because fuel is so cheap it is not regarded as economical to do so.

(4) We send goods in lorries rather than trains, and when a single person goes in a car nearly 50 times as much fuel is needed per person as when 7 passengers go in a microbus.

The problem is, of course, that as long as we rich people make this extravagant use of energy, the poor of the world will have a legitimate grievance, especially if a few rich people in their country emulate our extravagance. This grievance is the principal cause of the present world tension.

7.2 However, the main conclusion from this table is one of great hopefulness. If our skilled engineers, applied scientists and technologists diverted some part of the brain power they spend at present on war preparations, fashionable and totally unnecessary gadgets (e.g. games playing computers and particle accelerators) and on cars that will travel at twice the legal speed limit, then we clearly could give all humanity the benefits of the industrial revolution *within the limits of the renewable fuels.* The fossil fuels would then be sufficient to provide all the capital equipment needed to give us the ability to live on the renewable fuels and also several hundred years of fuels for premium purposes. These conclusions would not be upset even if the minimum figure was two or three times the one reached here.

7.3 The need to gather large quantities of wood fuel in poor countries is principally due to the lack of efficient equipment for using this fuel.

7.4 No account need be taken of the fossil fuels used to supply the initial equipment and infrastructure (e.g. roads and railways, drainage of sewage and land, irrigation canals) since these can certainly be supplied by diverting a fraction of the fossil fuel energy at present spent on preparing for war.

Part. II. How can this Energy be produced from renewable sources?

I. *Biomass as energy source.*

Much work has been done on the direct growing of crops for energy production especially the production of fuel alcohol from cane sugar and from cassava. There are proposals to grow and crop trees purely as a fuel source as was done in the "coppicing" process in Britain for hundreds of years leaving the roots to grow a new set of branches. As the pressure of an expanding world population makes human food the first priority it would seem best in the general case to use by-products of food crops and other crops with a direct human use, such as cotton or building timber, as fuels. There may of course be exceptions to this in cases where the land is not fit for anything else or where it is necessary to maintain an area with trees for ecological reasons.

Animal dung is dried and burnt in some areas, whereas the use of it in a methane generator provides a gas which can be used much more efficiently for cooking as well as providing a disease-free fertiliser. This process has been extensively applied in China and studies are being made in many other countries; in Mexico the use of solar heat to run the generator at 35°C, which is about the optimum temperature, is being studied. Let us suppose that half the protein of our villager comes from animal meat, the animals being fed on the leaf residue after protein extraction by Pirie's 1 af-fractionation process, which provides the rest of the protein. Then we can make a rough estimate of the amount of gas available: for each kg of meat protein the animal eats 20 kg of dry matter and excretes 15 kg of dry matter in the dung, equivalent to 7 kg of coal. If half this appears as CV in the gas (*Appropriate Technology*, P. Dunn, gives on p. 117: 250

litres gas/kg dry dung of CV 24 kJ/l. = 6 MJ/kg dry dung; this gives 3.2 KCE from 15 kg) and we take the total annual protein requirement as 38 kg/ca he needs 19 kg of meat and this gives a gas production of 19 × 3.5 KCE/ca = 66 KCE/ca. This is enough to do all the cooking and water heating a person needs (Item 5a, b, c of Table I), provided it is done efficiently, and it is very much easier to build an efficient gas cooker than a solid fuel one. The biogas is mainly methane and so a reasonably small village gas holder can make the gas available as needed.

Dunn also gives a figure of 450 litres of gas from 1 kg of dry vegetable matter, so straw and other by-products can be used in this way even more effectively, but it is probably necessary to have some nitrogen to ensure fermentation. Biogas can also be obtained slowly from the damp fermentation of wood chips.

The production of charcoal from timber is an old process, and indeed the use of charcoal in blast furnaces to make iron was causing the destruction of the forests of Britain in the seventeenth century until it was replaced by coke made from mined coal. This enabled our iron production to increase 100 fold in the latter part of the XVIIIth Century, illustrating clearly how dependent the industrial revolution has been on the use of fossil fuel, starting with coal. At first both charcoal and coke were made in the "beehive" oven in which a stack of raw material was enclosed in earth and fired with very limited air access so that only the volatile matter was burnt off, and no by-products were obtained. Later, processes were developed which heated the material through a firebrick wall (e.g. a coke oven) by burning a low grade fuel so that the gas and condensible products (tar and oils) could be recovered. The liquids with a high C/H ratio were used as chemical raw materials for a wide range of products until they were displaced by the petrochemical industry.

Wherever trees are grown and harvested for timber or paper production the use of the branches for making charcoal and by-products is worthwhile and small carbonizing equipment has been made out of oildrums. Charcoal can be readily crushed and sized whereas timber requires much more power for sawing it up into small pieces. Charcoal is also an ideal solid fuel for cooking because it can be sized and does not produce a smokey flame. In areas where timber is being harvested it can probably produce all the fuel needed for cooking and water heating (Item 5a, b, c of Table I).

Sized charcoal is also the ideal fuel for gas producers, as I know from our studies during World War II, where we had to develop gas producers for road transport with spark ignition engines, using much less convenient fuels. We found that only tar-free solid fuels such as anthracite or coke activated with NA_2CO_3 could be used, as tar clogged the filters too quickly. Charcoal is the most reactive fuel known for this purpose. Raw wood has been used successfully for stationary engines where the filter can be changed more often, and experiments are going on with other biomass, such as briquetted cotton plant waste. Producer gas from by-product biomass is thus a potential source of power for any of the items 2, 3, 4, 6, 8, 10, 11, 12 and 1b. It does, however, require equipment for gas cooling and cleaning and needs clinker removal every few hours, and the fuel must be sized within narrow limits, e.g., 10-25 mm.

There are areas which are only suitable for trees and here the growth of trees, such as eucalyptus, as direct biofuels may be justified, and the old English process of coppicing which leaves the roots to produce a new crop is worth considering — I am doing a small scale experiment, with 200 willows and 200 poplars along the side of a cereal field, planted on 1 m centres. It was suggested that once the roots were established, they could yield for many centuries at the rate of 12 T/ha.a of dry wood.

Experiments carried out in Sheffield 25 years ago showed that cotton waste was a very suitable material for conversion to oil by auto-hydrogenation. The hydrogenation process was used to produce petroleum from creosote in England in the 1930's at Billingham, but was stopped when large quantities of cheap petroleum became available. Hydrogenation of coal or coke was not found to be economically feasible, but a more reactive material and one already containing hydrocarbons or carbohydrates is a good feedstock. The necessary additional hydrogen can also be obtained from the fuel and this process is considerably more efficient than the Fisher-Tropsch process which gasifies all the fuel before the hydrocarbon synthesis.

However by far the most extensive use of fuel biomass will be the direct combustion in boilers to raise steam. This is because:

1. Steam boilers fired with biomass can be of any size from 1-2 KCE/hr to 10,000 KCE/hr (10 TCE/hr); the largest bagasse fired boilers are of this size.

2. They can be almost omnivorous, coping with large changes in size or character of fuel. The internal combustion engine, in contrast, is limited to a very narrow fuel specification and the gas producer is also highly sensitive to small fuel changes.

3. They can burn fuel with quite a high percentage of moisture.

4. Arrangements can be made to deal with high or varying ash content. Steam boilers are dealt with in Section IV below.

The figure of 10% efficiency of conversion from KCE(h) to KCE(P) in Table I is based on the assumption of a steam engine discharging at 1 atm pressure i.e. 100°C. If this steam is condensed and the heat at 100°C is used for cooking and water heating, then every KCE(h) of biomass used will provide not only 1/10th KCE(p) but also some 1/2 KCE(h) for col. 3. Thus, for example, if biomass is burnt to provide steam and power for items 4 and 8 of Table I then the steam can be condensed to provide *all the heat for item 5*, i.e., cooking, hot water for washing and boiled drinking water.

II. *Solar Energy.*

Many books are available and an enormous amount of work has been done on this subject, because of the vast potential of solar energy if we can only harvest it without too high a capital cost. The direct use of solar energy (i.e. not via biomass) can clearly supply all the items in Table I except 7b, 9, 10 and 11. However items 5a, 5b, 6, and 12 may have to be supplied in the evening after the sun has gone down. For example solar cookers give a hot meal in the middle of the day when it may be wanted in the evening.

To provide the total figure of some 300 KCE(h)/ca (i.e. cols 2 and 3 but excluding imports and transport) would require less than 2 m^2/c of solar collector in tropical sunshine, which averages about 300 W/m^2 over the whole year, if one assumes that only 50% of the sunshine was used as heat. Two square meters of solar collector for each person would provide all their needs except imports and transport, and 1 m^2 would be sufficient if the collection efficiency could be raised to 80% and 10% of the energy needs supplied by biomass or wind.

The conclusion seems clear that solar energy has a very major part to play in all tropical countries provided the capital cost can be brought down to a reasonable figure.

In our work at Queen Mary College we started from the assumption that the ideal system would be a combined heat and power system providing heat for items 5a, b and c as well as electricity or power for items 2, 3, 4, 6, 7 8, and 12, but that it must also have a storage system to provide both boiling water for cooking and also electricity in the evening after the sun has gone down. J. Lowry working in my Department, developed a low capital cost "power tower", i.e., a solar concentrator consisting of an array of mirrors reflecting the sunshine onto a blackened boiler surface on the top of a 5 m pole. In the first model the boiler area was 0.5 m^2 and the m mirrors consisted of 16 dishes with a total area of 23 m^3 giving a total concentration factor of 48:1. The upper surface of the boiler was insulated and the steam could be produced at 180-200°C. This steam could run a steam engine with 10% efficiency and exhaust at 100°C to a condenser which could be used for boiling rice, sterilising water or supplying hot water. Alternatively, the output of the boiler could be stored as superheated water at a pressure of 16 atm in an insulated battery of old gas bottles. Then it could be stored until evening and used for the same purposes, with a slightly lower power production efficiency, by flashing off the steam as the pressure was reduced.

Each reflector dish had an area of 1.44 m^2 and was therefore made slightly concave to focus on the 0.5 m^2 boiler. It consisted of 9 cheap thin back silvered mirrors 0.4 × 0.4 m mounted on a softwood frame, and each dish was pivoted about an axis parallel to the earth's axis so that in the tropics it is nearly horizontal. They are all joined together by a linkage mechanism so that the movement of a single lever can keep them all reflecting on to boiler as the earth rotates. This lever can be moved by hand every 5 minutes or a weight-driven mechanism can be made to do this.

No focusing system works when there is cloud cover and the system would give no output during the monsoon period, so that it would have to be supplemented at that time. However, a boiler fired with biomass stored for the occasion can operate the same steam engine and pass out heat system.

III. *Wind power.*

The power output (P) of a windmill depends on the cube of the velocity ($P = C_p \cdot \frac{1}{2} \rho \cdot U^3 \cdot A$ watts, where C_p is the coefficient of conversion of wind energy in the area swept, A m^2, and is the range 0.15-0.45. This figure can never reach unity because the air must move away behind the windmill with a finite velocity. ρ is the air density = 1.25 kg/m^3).

Thus for $C_p = 0.25$ we obtain power densities as follows:

U m/sec.	P/A w/m^2
5	20
10	160
15	530
20	1250

Thus the average windpower depends on the average of the cube of the wind velocity and windmills are therefore most useful in areas where the wind speed exceeds 10 m/sec for a large part of the year. For such areas a windmill rated at 11 m/sec will give some 200 W/m^2.

This could be used to provide all the power for items 2, 3, 4, 6, 7a, 8 and 12, in which case it would have to provide as power 17.1 KCE(p)/ca and thus save 171 KCE(h)/ca of other forms of energy. This is equivalent to 133 kWh/ca or 15 W/c continuous. Thus each person needs only 1/10th m^2 of windmill and even allowing for all inefficiencies 1/5th m^2 would be ample to provide all the essential power. This astonishingly small figure is obtained because the wind energy is directly available as electricity or power: if one were to use the wind energy to supply heat for item 5 then each person would need 60 KCE/ca or 466 kWh/a or 53 W/c continuous nearly 4 times as much as for all power requirements added together.

However, with wind power, as with solar energy, one must have an alternative source, or a storage system to deal with windless periods which may last several days. If the wind energy is used only for water pumping, such alternative energy may not be necessary, or a small diesel engine with a little fuel stored for emergencies may be quite sufficient. For other village purposes, however, a steam engine with boiler fired by biomass by-products, or a gas engine fuelled by biogas may be the best alternative.

Windmills can be horizontal axis or vertical axis; the former have to be turned into the wind. Both types require a tower to lift them above surrounding objects and to make use of the fact that wind speed increases with height above the ground roughly in proportion to the 1/5th power so that if one doubles the height one gains about 15% on velocity and nearly 50% on the power density. If hills exist locally the top of the hill is best. Both types are likely to be damaged in gale force winds unless specially designed precautions are used.

Low cost horizontal axis windmills are being developed by the ITDG (Dunn, *Appropriate Technology*, p. 132) and by Kentfield (Univ. of Calgary). For pumping, which requires low speed crank operation, they have many blades and a tip speed only a few times the wind speed. The crank raises and lowers a vertical pump rod which can work a piston type suction/force pump at the bottom of a deep well. For electricity generation they have a few blades with tip speeds up to 9 times the wind speed and usually run a generator situated at or near the axis.

The vertical axis generator has been developed in a simple practical form by Musgrove of Reading University with automatic compensation for high wind speeds (Dunn, p. 130). It has the advantage that the vertical shaft can drive a generator on the ground.

IV. *Steam Engines.*

Up to the beginning of this century small piston type steam engines were being extensively used and actively developed in the developed countries both for transport and for stationary power systems. The efficiency was raised by using high pressure triple expansion engines; but three was a limit to the maximum temperature of the steam set by the need to lubricate the sliding parts in contact with the steam. Since then the steam turbine has taken over for all larger purposes, and single stage turbines are available in Britain down to 45 kW for stationary purposes. These, however, discharge the steam at several atmospheres pressure so that they only convert a very small fraction of its enthalpy to power.

Enthusiasts, particularly in the USA, have built and operated successful steam cars but these are fired with liquid fuels and are usually non-condensing and hence of low efficiency. More efficient steam engines are also used on small motor boats where space and weight are not so critical and water cooling of the condenser is possible. One inventor in Britain is working on a small coal fired engine for motor boats.

Since the rise in oil prices 10 years ago there has been a realization that a solid fuel fired mono-tube boiler with piston type steam engine is likely to return to importance especially in areas where liquid fuels are unobtainable.

At QMC we studied (*Steam on Efficient Lines*, M.W. Thring, J.E. Sharpe and P.K. le Sueur Spectrum, 153/1977, p. 3) the possibility of developing a coal fired steam locomotive with as high an overall efficiency as a diesel/electric in spite of using a much more avaliable fuel. This was found to be a feasible proposition for a 4 MW condensing system using steam at 4.5 MPa (45 bar) and an exhaust pressure of 7 kPa (0.07 bar).

A combination of turbines and piston engines made it possible to have this very high expansion ratio. The system was to be fired by fluidised bed and this would enable any other solid fuel to be burnt. The condenser water is cooled in large radiators built around the engine units. This locomotive offers the possibility of high efficiency biomass fuel firing for very long hauls, and interest in it has been expressed in many countries where diesel fuel is not readily available.

Straw fired steam tractors were available in the 1920's but the development of the diesel engine has produced an alternative so convenient that no farmer who can obtain diesel fuel would want to leave it. However there are many places where diesel fuel is not obtainable or prohibitively expensive, and it seems that a biomass fired steam tractor will be of great value.

For this reason G.J. Meikle (Principal Research Engineer, Institute of Agricultural Engineering, Zimbabwe, Private Comm.) has been studying in detail a solid fuel fired tractor. He uses poppet inlet valves to enable the steam to enter the HP cylinder at 600°C with a superheat of 160-200°C and a working pressure of 11 MPa (110 bar). He proposed a monotube steam generator of the type developed for steam cars, with a maximum steam output of 420 kg/hr and a maximum coal input of 55 kg/hr. For the same calorific input, if straw were the fuel 110 kg/hr would be needed i.e. 6 conventional small bales when running at full power for the whole time.

It is interesting that a 200 kW reciprocating marine steam engine, fired on coal/oil slurry, is being developed by Prof Bullock and T. Heron at the University of Queensland with similar steam conditions. They plan to start at 550°C steam temperature, but eventually rise to 800°C using refractory piston caps and liners and special valving. It will be a compound engine with one HP cylinder and several LP cylinders to give a very large expansion ratio; there will be variable cut-off on the HP cylinder for power control. The cooler will be monotube.

A possible system for firing a tractor boiler with baled straw using the Down-Jet combustion system developed for coke and coal firing (*A method for the control of combustion reactions in fuel beds*, M.W. Thring, Trans Faraday Soc., vol. XLII, March 1946, p. 366) is shown in figure 1. This could give very good combustion control, i.e., complete combustion with less than 10% excess air, and very rapid response to the accelerator pedal.

If a small portable steam engine can be developed of say 2 kW operated on biofuel, then it will become possible to produce a "mechanical bullock", an agricultural power system which could be used for all cultivation and harvesting purposes. It would require much less land to fuel it than a real bullock and certainly in Bangladesh it has been estimated that there are less than half the number of bullocks needed to cultivate the land properly.

A real bullock has legs, which are a considerable advantage over wheels, for traction on fields. Fig. 2 shows a walking system which is extremely simple as it is operated by a chain drive using motorcycle type chains. This has the following advantages over a wheeled system:

1. It is very easy to change the feet for different soil conditions e.g. very soft soil, flooded rice paddies or very hard soil requiring spikes.

2. It moves forward with the foot in one place so that it cannot grind itself into the ground as a wheeled tractor does under high load in soft ground.

3. It damages a considerably smaller crop area than wheels.

Although the photograph shows a model with steering wheels in front like a conventional tractor, the mechanical bullock would in fact have the engine between the leg-pairs and be steered by long handles by the operator walking behind. The plough or other cultivation device would be carried between the feet.

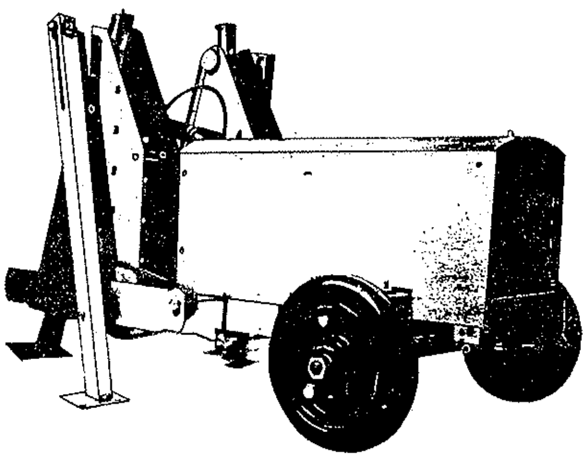


Fig. 2

V. *Conclusions of part II.*

It can clearly be concluded that the application of the materials and ideas available in the developed countries to the most important problem of the world — the desperate poverty of millions — could provide the technical solution to this problem in one generation. *But*, to do this it would be essential that a sufficient consensus of people in the rich countries should regard this as the most important problem facing them, and a sufficient number of people in the undeveloped countries would be prepared to cooperate by adapting their way of life to a sufficient extent.

All the essentials of a decent life could be available to all mankind within the earth's resources, if we were to regard the fossil fuels as a capital resource which must be used to provide the equipment to initiate the use of sufficient renewable energy.

SOLAR DISTILLATION FOR DESERT IRRIGATION

M. W. THRING
Queen Mary College
London, U.K.

SUMMARY.

A practical proposal is put forward for a low capital cost system for growing crops in desert areas by solar distillation of salt water, such as sea water. One half the area would be covered with stills and crops grown in the other half. A series of pilot plant experiments is recommended to establish the optimum design and cropping cycles.

I. STATEMENT OF THE PROBLEM.

Many areas which are now desert were fertile land before man overcropped them, and others were fertile when complex irrigation systems or dew collecting systems were used thousands of years ago. At the present time the deserts are growing — it is estimated that 21 million hectare per year of farmland (usually grazing) are degraded to desert every year (*New Scientist*, 10-5-84, p. 3) and that desertification threatens 35% of the earth's land surface and a fifth of its people. Africa, India and S. America contain the areas most affecting people. Classic sand deserts expand by sand blowing over productive land and the Sahara has expanded Southward by 650,000 sq.km. (1 sq km = 100 ha) over the past 50 years. Badly planned irrigation schemes can salinate the land.

It is clear that it is urgently necessary to reverse this encroachment on food growing land. Much can be done by better control of the fresh water already available in many areas, but there are others where drought periods are frequent, with disastrous consequences, and other areas where there are no rivers and rainfall may occur only once in several years. A scheme which would enable man to harness Nature's own method of producing fresh water — namely solar distillation of salt water — would clearly be of immense benefit to humanity if the capital cost can be brought low enough.

A scheme is proposed here which offers this possibility but would require several years of careful study on one or more pilot plants, before the design and operation were understood sufficiently for full scale installation.

II. Previous Work on Solar Distillation.

In 1872 a large greenhouse type still was constructed in Chile and produced 22.7 tons/day with a glass area of 4760 m^2. This is a layer of water 4.8 mm thick. Many small and large stills have been built for producing drinking water in arid zones and in emergency situations in sea and desert, and this subject has been extensively studied experimentally. More recently a small amount of work has been done on the problem of growing vegetables in arid zones.

The general principle of all solar stills is that the solar radiation passes through a vapour-tight sloping transparent cover, which may be of glass or thin plastic, but should be wettable on the inside, so that the condensing distilled water forms a thin layer which runs down the lower surface into a narrow trough along the lower edge. The salt water is contained in trays or basins with a black surface to absorb the solar radiation and so heat the salt water to a temperature more than 15°C above ambient. In one variant a tilted wick carries the salt water, and in another the salt water cascades slowly down a series of steeped troughs.

The thermal efficiency of a solar still is $\eta = \dfrac{A \times B}{C} \times 199\%$ where

A = yield of still in kg/m^2-day, or mm/day.

B = latent heat of evaporation of water 2.5×10^6 J/kg.

C = solar radiation in J/m^2-day.

Thus in hot regions where solar stills are used, the average daily solar radiation is about 2.3×10^7 J/m^2-day and a yield of 4.5 mm/day corresponds to a thermal efficiency of about 50%. This is equal to 1.64 tons/m^2-year.

Headley (Solar Energy, v. 15, p. 245, 1973) claims an efficiency of 70% using a specially designed cascade solar still (batch-type) with a secondary condensing surface underneath to give a high condensing ratio, thin layers of water to give a low thermal inertia, and a short distillation gap.

Eibling, Talbert and Löf, in extensive studies (*Solar stills for Community use.* Solar Energy, v. 13, p. 263, 1971) conclude that for large installations the simple ground-based basin still with a shallow basin (5 cm brine depth) and symmetrical double sloped glass cover at 10-20° to the horizontal is the most economical. The basin should be shallow so that it reaches as high a temperature as possible each day. Szulmayer (*Solar stills with low thermal inertia.* Solar Energy, v. 14, p. 415, 1973) has carried this to a logical extreme by using a black plastic solar absorbing surface which floats 3 mm below the brine surface so that only the top layer of water gets really hot. The main deciding factor is the capital cost for the total water production and plastic covers do not have a life of more than five years, so they must be cheap and easily replaced. On large units it does not pay to insulate underneath as the ground stays hot but on small units it is important.

The most important factor governing the output of a solar still is naturally the level of solar radiation, but with a given still the output goes up by a factor of 3.4 when the daily solar radiation doubles from 1.15 to 2.3×10^7 J/m^2-day, i.e. the efficiency nearly doubles. This is because a relatively small rise in brine temperature can double the evaporation rate, whereas the main loss of condensate is due to convective and radiative heat transfer from the brine to the cover and this only increases by a small amount. As the still gets older, however, losses due to vapour leakage through joints in the cover and to water leakage through small holes in the condensate collection channels become important and the efficiency falls.

Wherever the annual rainfall exceeds 25 cm/year, it is worth using the outer surface of the still as a rainfall collector. Floating stills have been designed to condense the evaporation from a brine pond, and others have been used to collect water evaporated from the earth or desert sand. Cut up plant material can be used to increase the output from such a still.

Preliminary experiments have been carried out on multiple effect stills and Telkes (*Solar Still Construction*, OSW Report No. 33, PB 161404, Aug. 1959) has estimated that a tilted 10-effect solar still would give 6 times the output of a single effect solar still of equal area. However the object is not to save energy as in fuel heated evaporation, and it seems unlikely that the capital cost could be made as low as that of a single effect still of the same output.

Trombe and Foex (Utilization of Solar energy for simultaneous Distillation of Brackish Water and air conditioning of Hothouses in Arid regions, UN Conference on New Sources of Energy, Paper 35/S/64, Rome, Aug. 1961) first proposed the use of a combined still and greenhouse for growing vegetables. The salt water is placed in tanks just below the roof of the greenhouse so that they shield the hottest sun from the crops below and the saturated hot atmosphere in the distill-roof is sealed from the lower part and the distillation water runs down through tubes. Selcuk and Tran reported the use of this idea in Turkey (*Solar stills for Agricultural Purposes.* Solar Energy, v. 17, p. 103, May 1975). They found that their measured distilled water output was some five times the calculated evapo-transpiration from the crops below when they used fan propelled air for ventilating the crop area cooled by spray humidification. Outside in an arid zone this evapo-transpiration rate could be 12 kg/m^2-day so that it is essential to reduce it in some way such as shielding the crops from direct sunlight.

III. A PROPOSAL FOR GROWING CROPS ECONOMICALLY IN ARID LAND BY SOLAR DISTILLATION.

It has been estimated (Brian Colquhoun and Partners, Solar Distillation and Crop Production in Kuwait, Private Comm., March 1975) that a city of 750,000 inhabitants consumes about 250,000 ton/annum of cereals, fresh fruit and vegetables and that it would require some 4 Mtons/day of fresh water to produce this quantity of food. Per head these figures are 330 kg/ca of food requiring 5.3 t/day-cap. or 1930 t/ca of fresh water. Thus if the evaporation and distillation rate in the desert area is 5 mm/day (5 kg/m^2-day) then each person would require a distillation area of about 1000 m^2 or 1/10th hectare. If the irrigation of land requires 8 mm/day and the crop production is 4.5 t/ha-a (three crops a year) each person will require a crop area of 730 m^2. Thus 3/5 of the total area would be distillation area and 2/5 crop growing area.

There is, however, a practical way of improving this ratio to better than 1:1, perhaps even to 2:1, i.e., 1/3 still and 2/3 crop area. This follows from the fact that most of the water requirement is for thermal transpiration to keep the plant cool, so that if one can shield the crops to reduce the direct solar radiation to a fraction of its full effect then the plant can grow with considerably less water requirement. This may be done, as in the greenhouse of Selcuk and Tran, by putting the solar evaporators above the crops in a sealed separate space to prevent the very hot saturated air above the evaporator from reaching the crops. However a framework to support a water tank high enough above the crops for people to work on them would be far too expensive for the large areas we have to consider, while land area is cheap so that the distillation area and crop growing area should be side by side. Another way has been developed in Botswana (*Appropriate Technology*, v. 3, No 1, p. 15, May 1976) in which the crops are covered with a fine mesh white nylon net giving a high shielding ratio and supported at a suitable beight with poles.

This network may also recondense a proportion of the vapour from the plants, and at night it may also increase the dew deposition if it is black for low temperature radiation, by cooling to a lower temperature than the ground would reach. The air inside will become saturated at night and dew will form also on the inside of the net. Pirie (*Food Resources*, Penguin, 2nd Edn, 1976, p. 45) says that the dew that can be collected in a desert area is not likely to exceed 25 cm/a or an average of 0.7 mm a day. If this can be increased it can become a significant fraction of the crop requirement of 8 mm/day, especially as the dew on the outside of the still area can also be used, as can the occasional rainfall on both areas.

Fig. 1 shows a feasible design for a first pilot plant trial. Each unit of the still consists of an area of levelled ground (5 m × 5 m) lined with black butyl rubber and bordered with concrete walls (W) cast in situ, to form a basin which is filled with water daily to a depth of 5 cm. Each unit is covered with a thin plastic transparent roof (Y) similar to those used in greenhouses. The roof is sealed to the concrete walls all round and is supported either (1) by a central fibre glass reinforced plastic partition as at A-A, (2) by a central pillar as at B, or (3) held up in an arc by a small excess air pressure, e.g., 1 mbar which is sufficient to support a roof weighing 10 kg/m^2 and to give tension on any lighter weight roof.

Each still must be accurately levelled as the water should not be more than 5 cm deep and there must be no dry spots, but each still can be at a different level from its neighbours when the ground is not level

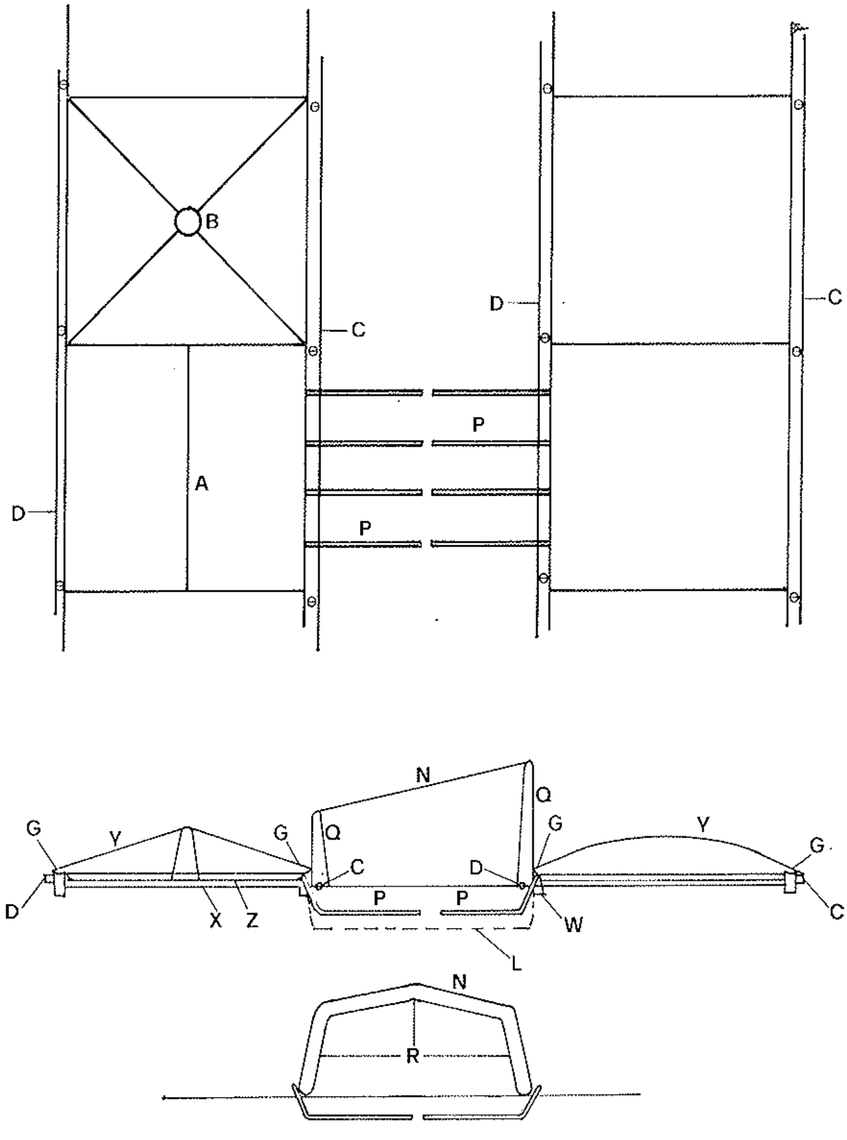


FIG. 1. General Loyout of Unit Stills.

Scale 1:100

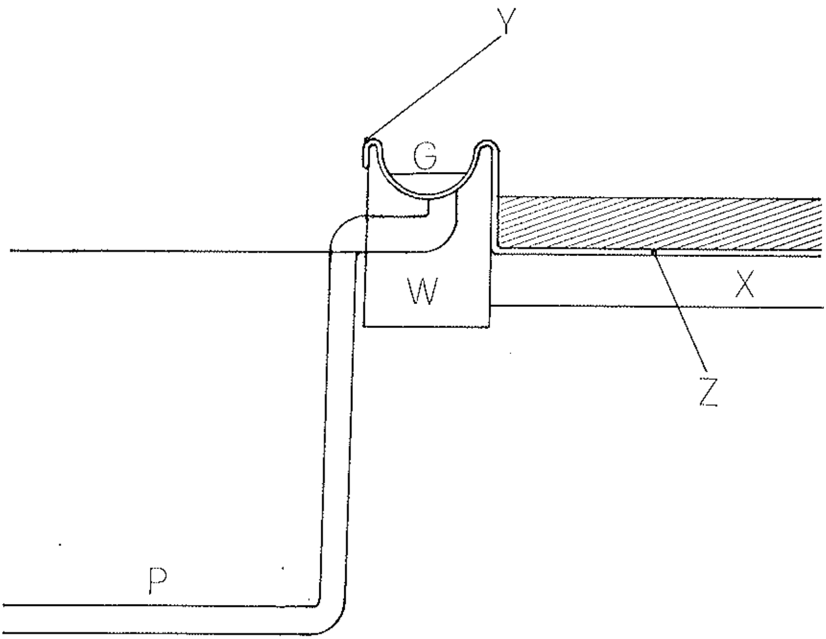


FIG. 2. Details of Gutta.

Scale 1:5

The stills are laid in rows with a strip of ground 5 m wide for crops in between each row of stills. Thus half the total area is covered with stills and half with crops.

The sunshine passes through the roof and is absorbed by the sea-water and the black plastic base. It heats the water up quite quickly and evaporates it, so that it condenses on the inside of the roof and runs down the slope to gutters G-G, which are connected to a series of porous or slotted plastic pipes P-P buried under the crop area at a depth of 30-50 cm to irrigate the roots. The optimum spacing and depth of these pipes, which need be only 25 mm diameter, has to be ascertained by the pilot plant experiments, and may vary from area to area according to the local soil conditions. It may also be necessary in some areas to insert an impervious layer L at a depth corresponding to the maximum desired root depth to prevent loss of water downwards. In other cases, however, it may be desirable to cultivate permanent rows of deep-rooting plants such as trees or lucerne (alfalfa) whose roots will bring up fresh water from below.

Every night a certain fraction of the partially concentrated brine is run off through pipes C and next morning fresh sea water is pumped in through pipes D to replace the 5 mm of evaporation and the amount run off. Alternatively none would be run off for several days and only the evaporated fraction replaced until the brine was nearly saturated, when it would all be run off and replaced.

In either case the concentrated brine would be run into open basins with concrete linings, where it would be left to evaporate completely to salt, which could then be scraped up and used as a source of K for fertilizer and other salts (e.g., Mg salts) which could be extracted and processed for various purposes.

Over the crop areas the fine mesh white nylon nets would be supported either by posts as at Q or by inflated plastic tubes (0.3 m dia. and 2.5 m apart) as at R. These would block off 1/2-3/4 of the sunshine and reflect it back without getting very hot themselves; they would be best if they also had a very high emissivity for long-wave thermal radiation so that they cooled rapidly at night. They would be high enough that the crop attendants could work standing up and use either hand tools or low HP hand steered cultivators, and they would have arrangements to ensure that the condensate dew or any rainfall dripped onto the crops.

IV. Pilot Plant Studies.

Clearly it is necessary to set up at least one and preferably two or three pilot plants in different arid areas before any full scale crop growing installation is even planned, in order both to develop the best engineering design of still and crop cover (to combine lowest costs with good performance and durability) and to work out the best agricultural use of the land irrigated.

4.1 *Engineering Design problems to be studied.*

4.1.1 Still Roof Materials — type of plastic, thickness, lifetime.

4.1.2 Roof support method.

4.1.3 Cycle of evaporation and processing of salts.

4.1.4 Best method of gas-tight sealing of roof to walls and tank lining.

4.1.5 Collection and distribution of distilled water underground.

4.1.6 Preparation of ground.

4.1.7 Material and support of crop solar shield.

4.2 *Agricultural Studies.*

4.2.1 Testing various crops and crop rotation. How many crops per year?

4.2.2 Fertilisers needed.

4.2.3 Desirability of planting trees, say, every fifth row. Could one ultimately obtain enough rainfall without the still roofs?

4.2.4 Need for an impervious layer below?

4.2.5 Soil preparation? Cultivation, ploughing etc.

4.2.6 Weeds, insect pests and plant diseases?

4.2.7 Optimum irrigation rate.

4.2.8 Optimum shielding ratio of crop roof N?

A pilot plant must therefore be large enough to give answers to all these questions. If it were 1/4 hectare (2500 m^2) and square it could have 5 lines of stills and five lines of crops each 50 m long — this is about the smallest that would be significant. After 3 or 4 years' testing there would probably be enough engineering data to enable a larger pilot plant to be designed and built for more extensive agricultural tests.

PROPOSALS FOR LOW COST FERTILISER PRODUCTION

M. W. THRING
Queen Mary College
London, U.K.

SUMMARY

It is suggested that the best way of enabling people to grow more food for themselves is to find ways of producing locally fixed nitrogen so that they can increase their output of their traditional crops. One way would be to have a farmers' cooperative using an agricultural by-product, such as straw, as fuel for the Haber-Bosch process. Another way would be to recycle the nitrogen in city night soil.

I. STATEMENT OF THE PROBLEM.

There are three main factors that have caused the production rate (Tons/Hectare-annum, t/h.a.) of wheat and other cereals to increase four-fold in the last hundred years in Britain.

(1) The use of large quantities of Nitrogen (at first from guano, imported, and now from atmospheric nitrogen fixed by the Haber-Bosch and Fauser processes, and, if very cheap electricity is available the electric arc process) as well as P and K in smaller quantities for additional fertilisers. The N and P had previously been supplied mainly by farmyard manure (e.g. rotted straw which had been used as animal bedding and rich in urea). Bones also contain P while K was available in wood ash.

(2) The development of special high yield crop varieties putting much more weight into the grain and less into the straw; for wheat the straw+chaff used to weigh 2-3 times as much as the grain and now the weights are roughly equal. Such high yield varieties are, however, much more susceptible than the old long established crops to pests and

diseases; indeed we have to change the strain every few years because of disease.

(3) Sprays to kill insect pests and prevent disease have been developed and must be used several times a year.

It is likely that the most important way of enabling poorer agricultural areas of the world to increase their production rate is to concentrate on the first of these three factors, i.e. to continue to grow their traditional crops but to find a means of enabling the poorest farmers to afford a supply of N, P, K, sufficient to double their crops. Water is, of course, also in many areas a major problem but here I am concerned only with the supply of fertiliser.

In the early 1970's world production of N in compounds was 40 Mt/a (actual N content) and 80% of this was used as fertiliser. N is readily leached into runoff water where it is positively harmful resulting in eutrophication of rivers and lakes and nitrates in drinking water. It is the most important fertiliser for increased yields.

P comes mainly from phosphate rock and phosphatic iron ore. Extensive reserves of phosphate rock are available in N. Africa, Florida and USSR but many other countries have sources. Basic slag from steel-making with phosphatic ores used to be widely used in Britain as it was also a source of Ca for reducing soil acidity. 80 Mt/a of phosphate rock were mined in the 1970's. P does not leach away but if a soil is initially low in P it may be necessary to build up the soil content by initial massive dosage.

K does not leach away readily and so does not require great annual additions. However, some 20 Mt/a of potassium salts were mined in the 1970's mainly for fertiliser. K is the seventh most common element in the earth's crust and appears mainly in low proportions in minerals, but as concentrated deposits in USSR, Canada and Germany. Probably many other deposits are available.

Each ton of wheat and peas grown takes *from the land* the following weights:

	kg/t wheat grain taken		kg/t peas
	in grain	in straw	
N	30	—	—
P_2O_5	8	1.6	7.6
K_2O	5.6	8.2	10

(Peas, being a legume, fix their own nitrogen)

These quantities, therefore, must be replaced for each extra ton of crop taken off the land.

In the next two sections of this paper I give some brief preliminary suggestions for two methods of obtaining cheap fertilisers in a country that cannot afford to import them.

II. The Fixation of Nitrogen using agricultural by-products as a source of energy and H_2.

In the Haber-Bosch process ammonia is produced from a mixture of H and N by reaction at a temperature of about 500°C and a pressure of 1000 atm., with an iron catalyst, according to the reaction

$$N_2 + 3H_2 \rightarrow 2NH_3$$

The appropriate mixture of N_2 and H_2 is made from coke, petroleum or natural gas by reacting with air, oxygen and steam. The original process involved alternately blowing the bed of coke with air (to make Producer Gas, CO, CO_2 N_2 and raise the temperature) and then with steam to make water gas (CO, CO_2, H_2) which dropped the temperature again. Both gases were then reacted with steam at a temperature at which the water gas reaction

$$CO + H_2O \rightarrow CO_2 + H_2$$

is almost complete, and then the CO_2 is dissolved in water at a pressure of about ten atmospheres, leaving only N_2 and H_2 in the product gases.

When starting with a fuel such as petroleum or methane which contain a considerable proportion of unoxidised hydrogen, less fuel is required to produce the final product than when coke which is almost pure carbon, is used.

Water gas can be made by a continuous process if an oxygen/steam mixture is used and the nitrogen obtained from a separate reaction (e.g. from combustion gases from which the CO_2 and H_2O have been removed) or the two processes can be combined by using an air/oxygen/steam blow.

The ultimate analysis of wheat straw is given (*Cereal Straw*, A.R. Staniforth, Oxford 1979, p. 37) as

	% by weight
C	43.3
H	5.3
N	0.9
S	0.1
Ash	4.2
Moisture	10.0
O	36.2

The high oxygen content is the cause that the calorific value per unit weight is only about 1/3 that of oil. The CV is about 16 MJ/kg at 16% moisture compared with that of oil (diesel) of about 42 MJ/kg. Diesel oil has a C/H ratio of 6.4 (85.7% C, 13.4% H) compared with 8.17 for wheat straw with the above ultimate analysis. Coke however has a very large C/H ratio ($\sim$ 200). Thus wheat straw is inherently a much better fuel for producing H_2 than is the classical fuel, coke, but not so good as diesel oil or natural gas (C/H ratio 3). Compared with coke, straw also has a lower ash content and is a much more reactive fuel so that it can react at lower temperatures.

The total fossil fuel energy required to make and supply to the farmer 1 kg of N as ammonia is 60 MJ/kg and the average for all forms of N is 67 MJ/kg N (i.e. 2.4 TCE/T N), that is, one ton of N requires 2.4 tons of coal equivalent to make it). If we take this latter figure the *energy required to produce the* N *required for one extra ton of wheat is* 2.0×10^9 J *or* 71 kg *coal equivalent* (KCE). The energy requirements to produce the extra P and K for this ton of wheat together add up to about 1/10th of this figure, so they must be regarded as minerals rather than as energy sinks. Even the direct fuel (diesel) used in Britain for cultivation and harvesting is only about 1/3 of the energy needed to fix the N. This is why the rise in the cost of fossil fuels over the last ten years has made the cost of N a very large item in the cost of a farm in Britain which produces yields of 7.5-10 T of wheat/ha.a.

The straw from 1 T of wheat has also a weight of 1 T if it is high yield short straw wheat of modern type, or of course 2-3 T if it is the long established type. 1 T of straw has a calorific value of 16×10^9 J/T or 570 KCE/T. Thus it has enough energy to produce the fixed N for 8 T of wheat the next year, and even if straw can only be converted with one-half the efficiency of coke it will still produce the N for an extra 4 T of wheat.

Thus the basic problem is to develop a gasification process for straw so that it can be used as the source of H_2 for the Haber-Bosch process and also a combustion process for a high pressure steam raising boiler. These research projects are clearly of great importance both for the developing countries and also in the developed countries, where they could save fossil fuels, produce cheaper N and eliminate the straw burning hazards.

The biggest problem in using straw as a fuel is the harvesting from the fields, transporting to a central plant and the handling into the combustion chamber or gas producer. A nitrogen fixation plant has to be of a certain minimum size, and this would necessitate a farmers' co-operative carrying the straw a distance of up to 10 or even 20 km so that the straw would have to be baled to as high density as possible. A conventional small baler produces bales weighing about 18 kg and of dimensions $0.36 \times 0.46 \times 1.0$ m^3. It thus has a density of about 0.11 but this can be pressed down to a density of 0.16 by using more power and modifying the baler or even 0.22 by using a more expensive baler.

Any system using the straw for nitrogen fixation is, therefore, dependent on the use of tractors of some 30 kW for baling and lorries for transport, although both these can be used on a cooperative basis. The only fuel use for straw in a village in the first stage of development is hand firing of loose straw for small boilers, but it would seem that one of the best ways for a wealthy country to help a poor one would be to provide the machinery for a farmers' cooperative for Nitrogen fixation, once the process has been worked out.

For baled straw transported some distance combustion on a grate or the Down-Jet system of fig. 1 are available. Bagasse (sugar cane refuse) has been burnt in large boilers (up to 120,000 kg steam per hour) with (1) spreader stokers with travelling or dumping grates for ash disposal (2) chain grate stokers.

For the gasification required for the Haber-Bosch process with an air/oxygen/steam blast the Down-Jet system of fig. 1 would be a possibility worthy of experiment; alternatively a gasifier like a small blast furnace with a double bell system to take whole bales could be used.

For the largest scale combustion of straw for raising high pressure

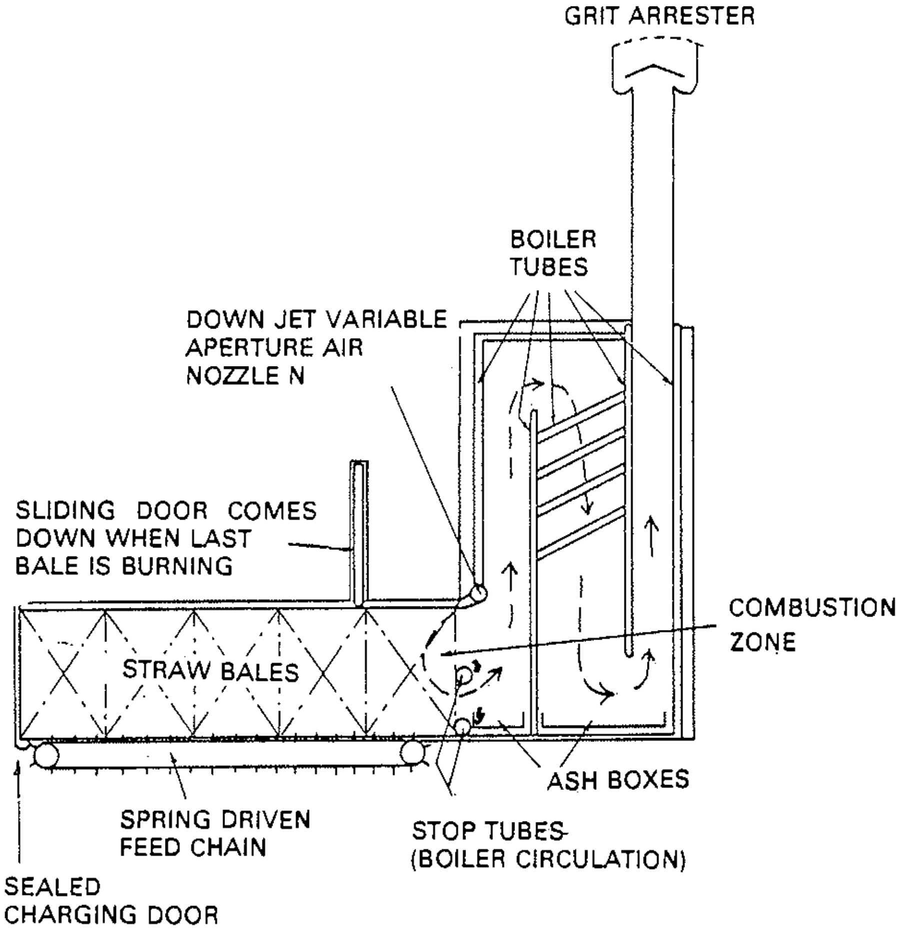


FIG. 1. Possible arrangement for high intensity combustion of straw bales (purely schematic).

steam or for drying processes of lime burning, the following methods are feasible:

(1) Chopping and burning in cyclone furnaces.

(2) Fine chop and burn as pulverised fuel.

(3) Step grate combustion of whole bales.

(4) Spreader stoker.

III. Fertilisers from city night soil.

Most of the Nitrogen in food is passed to city and village night soil, but much of this is in solution, especially urea. Urea is a very valuable material both for crop fertilisation and as an additive to animal feedstuffs.

The basic problems of using night soil, soluble and insoluble components as fertilisers are:

(1) Destruction of disease bacteria.

(2) Dilution with large quantities of water.

(3) Poisonous m tals esp Zn. If factory waste water is admixed there may be others.

In Britain, when I was a boy, the earth closet was still in use in country areas and the result was dug into the garden. In the last century farmers in Britain were advised to replace guano as a source of nitrogen by using 5000-10,000 tons of wet sewage per acre. (*Sewage Irrigation Farms in the XIXth Century.* C.E. Fussell, Agriculture LXIV, 1957-8, p. 138). In the 1980's sewage irrigation systems for pasturage, vegetables and cereals were used from over 100 towns in Britain. However, owing to the extreme dilution, the main result effect was the irrigation and this was valuable in dry years but harmful in wet ones. The slurry required large land areas for storing it in the winter when the water was harmful on the land.

Some of these disadvantages may not apply in dryer climates, and it may be possible to operate sewage systems with considerably less water. The disease problem can perhaps be overcome and methane produced even on a city scale by the wet fermentation process much used in Chinese villages. The heavy metals need not find their way into the sewage to nearly such a great extent and indeed it is very wasteful to wash them away.

This is clearly an area where research related to particular cities would be of great potential importance to all humanity.

DISCUSSION

EDEN

In your paper, Dr. Landsberg, you express the opinion that it is a misconception that developing countries will be the main source of pressure on oil supplies worldwide, and that they need oil as a major component of their development. It seems to me that the subsequent part of your paper shows that this is not a misconception. There is indeed an enormous need for oil in the developing countries. I think it will be unfortunate if we get the impression that LDCs are not very dependent on oil.

A remark on Dr. Thring's talk. It is stimulating to have an engineer evaluate what can be done in ideal circumstances. Too bad one always has to face the decision-making problem: even if things are ideally possible, they can not always be accomplished.

SUAREZ

Prof. Landsberg, let me remark on certain points that you presented in your paper and on which I disagree. I would like to just list them.

In the last few years, the debts and the high interest rates in some countries have been even more important than the oil bill. Today other reasons, different from non-urban pressure on wood fuel, continue to play a key role in deforestation. About promotion of exports by LDCs, how can they succeed when developed countries close the market and pull down international prices for raw materials?

About oil production I have many doubts. The drilling in LDCs has languished because the size of the reserves is not interesting for multinational oil companies, or they propose commercial agreements that host countries are unwilling to accept. Could you please elaborate on the concept of « individual companies » a bit more? Are you referring to national companies or to independent ones?

Finally I would like to comment on your point that changes in income distribution are the best way out of poverty. I think that adequate tariff structures for electricity and natural gas can help income distribution and electricity penetration in the short term. This starts the reinforcement of the process of income, energy consumption, higher efficiency, higher income.

In our surveys we have also found that refrigeration and cooling through fans, irons, radio sets, TV sets, rank high in poor households. For us that shows, first, that cooling is as basic a need in hot climates as heating is in cold ones. Recreation is also a very basic need. People do everything they can to get these things to satisfy them. If they really buy TV sets, and Mr. Landsberg said: « I do not understand how thay can do it because they cannot, but they do », it is because they have some saving capacity. Why not use the same mechanism to diffuse cooking stoves, or other more essential equipment? Maybe we have here some kind of disguised service production activity developed in households. The real needs have to be identified if one wants governments to take the right of decision. Let me finish by saying that I agree fully with you, Dr. Landsberg, on your conclusion that we need more case studies, and very analytical ones.

GOLDEMBERG

I just want to make a clarification about one interesting point made by Dr. Landsberg. I am quite aware that ethanol production is very site specific. However, fuel for transportation is a very important ingredient in the overall world energy picture. Approximately one quarter to one third of the energy consumed is spent in internal combustion engines. Very great efforts have been made to develop fuels from biomass or from biogas, which are less site dependent. I would like to mention that great efforts are being made to produce ethanol from natural gas, which is based on a well-known technology, and also from biomass which will not be site specific, because you can use trees and any kind of biomass as a raw material. This is much better than sugar cane, which is quite site specific.

CARTER

There are two points that I want to pick up in Professor Landsberg's paper. One we discussed yesterday is the need for accelerated exploration for oil in some of the oil-importing developing countries. How to overcome this problem of the limited size of the field and the resources, coupled with, I think, an innate suspicion and lack of experience of some governments in these countries concerning the operation of multinational oil companies. It seems to me, whether the suspicions are justified or not, that the attitude taken by the American government in dissuading the World Bank from playing a more positive role is most unfortunate. There might be a case for setting up some sort of independent advisory centre or coming to some considered views on taxation, operations, and similar actions.

The second point I would like to make regards the conservation aspect of Dr. Landsberg's paper. I agree, of course, with what he said about the importance of this, the obstacles that lie in the way and the need for much greater priority for this area. I think this is a problem that has to be tackled in a disaggregated way according to the circumstances of the individual countries. But I really think that we do already know quite a lot about this problem, although I think it is essential for more case studies to be done. It seems to me that very often we are calling for more information and what we lack is commitment by government for action policies to be developed and actions to be taken. We need political commitment by the governments now.

Smith

I have a question for Dr. Landsberg. Although your talk and Prof. Thring's seemed quite different, it might be said that both fit under the energy « Weltanschaung » that develops in a conference like this. And since you have taken a case study approach, which I think is very important because generalisations have been made much too often without looking at the actual facts, let me ask the question: Do you find in these case studies places where energy is the most important constraint, that is, is it worth looking at energy separately from all the other factors related to development? Is energy a useful tool to improve life compared with other ones, like education, health care, and so forth?

Boettcher

A technical comment on Dr. Landsberg's consideration on windmills. Your group found out that windmills with vertical-axes were of less use than ones with horizontal axes.

It is my opinion that both types of windmills have the same commercial potential.

Zeghbib

Regarding risk evaluation in exploration, Dr. Landsberg, you have confirmed today what Mr. Desprairies said yesterday: that political risk plays a very small role in the decision-making of the multinational companies.

I wonder if we are talking about the same thing. If we take cases in which the oil company was already present when a major political change occurred, then they had to stay. At the same time, government had a great interest in having oil production continue. But if we are talking about what is happening today, after the 1973 oil crisis, things are a bit different. Oil companies have world maps on which the different countries are classified according to political risk. Surely political risk plays a minor part where there is an evident economic profit; for instance, where you have reserves of a given size.

I agree with Dr. Landsberg that rural electrification is not sufficient. It has to be coupled with other infrastructures, investments, and social programmes, as Dr. Smith pointed out.

LANDSBERG

I shall try to be very brief, also because for some of the questions I do not have an answer, since I was not involved in all the projects of Resources of the Future.

On the subject of incentives to oil exploration development in the non-oil-producing countries, I think we have come back to this issue again and again. Some work is going on in my organization on that particular subject and we hope we will reach a solution in the near future. On the specific point of political risk, all we have found so far is that it is less important than people thought 5-7 years ago. We have also found that industry people in the energy field do not have a very explicit definition of political risk. It is more a subjective judgment than the application of some rule.

Dr. Eden raised the first point. Allow me to make a clarification. What has happened is that in the last few years LDCs did not have the resources to buy enough oil to put pressure on the oil market. It has nothing to do with the continuing need in the abstract sense, or that they will not continue to be high priority customers. What has happened is that a rather casual assumption on the existence of a great reservoir of demand simply is not true.

Mr. Suarez' disagreements are of great importance and useful to me. On the question of high interest rates and indebtedness, we simply did not address the subject, but it leads me again to the comment that energy problems are part and parcel of much larger problems.

The point that Dr. Goldemberg made on ethanol is quite true. The search for an organic source that is not site dependent is very important.

I accept both of Jane Carter's comments. We know a great deal about conservation. It is a commitment governments have to make and they dislike dealing with an enormously fragmented clientele. It is much easier to deal with big projects such as large power plants.

I cannot answer Kirk Smith's question. We did not ask ourselves whether energy was the most important tool. It is a vital input, but by itself it could not achieve anything. With complementary inputs it can do a lot.

I accept Dr. Boettcher's remarks on windmills. I am sorry that I cannot provide more information on the subject, but I do not have it here.

Mr. Zeghbib raised an important question, again, on the oil risk. We are continuing to work on it. We are trying to define, among other things, the hierarchy of the barriers. I also agree that there is a very important cultural aspect in the utilization of fuel wood, and we are doing some studies on that.

THRING

I feel that we are all looking at the energy problem from above, and that we ought to look at it, caring for those people for whom energy is a problem, from below. They are in trouble now, and it is no good to do case studies for the next ten years. They need action now. It is clear from what we have heard that politicians will not solve it because they are always much too concerned with prestige, and the international companies are concerned with profits. We need people who will care and take action. We spend too much time discussing what we are going to do for the next ten years without doing anything.

CHAGAS

It seems to me that we are dealing more with quantitative than with qualitative value. I feel a little anxious, because we are dealing here with what is also dealt with by major companies, governments and financial agencies. That is absolutely right, but we should also treat the other side of the question, in which we have to see what is happening to the poor. We have to help them, let us not forget it.

A VIEW ON ALTERNATIVE ENERGY DEVELOPMENT IN SOUTH-EAST ASIA

KAZUAKI MATSUI
The Institute of Applied Energy, Japan

KEICHI OSHIMA
The University of Tokyo, Japan

In the face of the 21st century, the "Asian Pacific basin" is attracting attention as an area where the highest growth can be expected in the process of future development of the world economy. The reason, needless to say, rests on a formidable potential growth power of the area. According to a general geographical definition, countries included in the Asian Pacific basin are those located in the Far East and East Asia including Japan, South Korea, China and Taiwan, Southeast Asian countries with ASEAN members as the centerpiece, South Pacific countries including Australia and New Zealand, and countries located along the Pacific coast of Central, South and North America.

These countries are diversified and include industrially advanced countries, resource-rich advanced countries, newly industrialized countries (NICs), resource-rich developing countries and non-resource developing countries. Their large populations and racial diversification also form critically important factors in our considering the size and diversity of the potential market.

In the paper, I like to review energy supply and demand, and alternative energy developments mainly in South-East Asia.

1. *Energy Supply and Demand in South-East Asia*

Different Asian countries feature quite different situations. Without fully realizing this point, to make simple comparisons among different countries is not only insignificant but dangerous. Therefore, to clarify different situations in different countries, discussed at the beginning are situations of the Philippines, Indonesia, Malaysia and Thailand in Southeast Asia from such aspects as national conditions and energy situations. While making comparisons among these countries, situations of South Korea and Japan in East Asia are also discussed to provide references.

Table 1 compares national conditions of different countries. In terms of GDP, Indonesia shows the highest of some $ 70 billion (about one fifteenth of Japan's GDP). However, because the country has a large population of some 150 million, GDP per capita turns to be $ 470 (about one nineteenth of Japan's), the lowest among the five countries. Forming a striking contrast to Indonesia, Malaysia marks the lowest GDP but the highest GDP per capita among the five countries. Thus, it can be interpreted that Indonesia outpaces Malaysia in terms of national capacity, while Malaysian people enjoy more affluent life than Indonesian people do.

Looking at overall energy situations including electric power, South Korea uncompetitively outdoes the other four countries (with its power output per capita standing at about 1/4.5 of Japan's), though the country belongs to newly industrialized countries (NICs) in terms of national capacity.

Tables 2 and 3 indicate energy consumption at present and in the future, respectively. Reviewing current energy consumption, it is noted that large amounts of energy classified as "others" are consumed in these countries excluding South Korea and Malaysia. Energy sources included in "others" are primarily non-commercial energy, such as firewood/charcoal, straws and bagasse, of which consumption can naturally grow in these countries where energy distribution systems have not yet been developed. In Indonesia, the nation consisting of the largest number of islands in the world, the share of non-commercial energy reaches as much as 60%. In South Korea the share of non-commercial energy is 5.4%, which is understandable, while 2.4% in Malaysia seems to be questionable. A report says that non-commercial energy accounted for 18% of Malaysia's total energy consumption in 1978.

All of the five countries show high ratios of oil to total consumption of commercial energy. Therefore, to reduce their oil dependence, they are now making efforts for diversification of energy sources by introducing alternative energies. Such moves are a natural course to be taken by countries not blessed with oil resources. Apart from them, however, resource-rich countries (Indonesia, Malaysia) with abundant oil, gas and others are also adopting a policy to reserve oil and natural gas for exports:

TABLE 1 - *National Conditions of South-east Asian Countries* (As of 1980).

	South Korea	Philippines	Indonesia	Malaysia	Thailand	Japan	Singapore
Population (mil. persons)	38.20	47.91	147.49	14.01	46.46	116.80	2.40
Land Area (10^3 km^2)	99.00	300.00	2,027.00	330.00	514.00	372.00	0.60
GDP ($ 1 billion)	54.49	35.07	69.83 77.40 (1981 ADP)	23.03 24.80 (1981)	32.66 36.00 (1981)	1,040.00 1,139.50 (1981)	12.50
GDP per capita ($)	1,426.00	732.00 783.00 (1981)	473.50 520.00 (1981)	1,643.70 1,740.00 (1982)	702.90 770.00 (1982 GDP)	8,904.00 9,689.00 (1981)	5,743.00 (1982)
Power generation (10^6 kWh)	37,239.00	15,095.00*	6,656.00**[a]	8,974.00	14,754.00	514,000.00	
Power generation per capita (kWh)	975.00	315.00*	47.80**[a]	640.00	317.60	4,409.00	
Commercial energy consumption per capita (kg • coal equivalent)	1,473.00[a]	329.00[a]	225.00[a]	713.00[a]	353.00[a]	4,048.00[a]	

[a] 1979 values.

* The figure covers only generated output by the Philippine Electric Power Corporation (NPC). In addition to the power generation shown, non-NPC generated output is available, amounting to some 15%.

** The figure covers only power generation by the Indonesian Electric Power Corporation (PLN). Non-PLN generated output is estimated to amount to the same as PLN's.

Sources: Key Indicators of Developing Member Countries of ADB (ADB, Oct., 1981); World Development Report 1982 for Japan's figures.

TABLE 2 - *Energy Consumption in South-east Asian Countries.*

(Unit: million kℓ oil equivalent)

	South Korea [a] (1981)	Philippines [b] (1981)	Indonesia [c] (1978)	Malaysia [d] (1980)	Thailand [e] (1981)	Japan [f] (1980)
Oil	31.20 (58.40)	11.60 (56.60)	21.20 (35.10)	9.32 (94.40)	11.96 (68.40)	284.90 (66.40)
Coal	17.70 (33.10)	0.22 (1.10)	0.22 (0.36)	—	0.50 (2.90)	71.60 (16.70)
Hydro	0.80 (1.50)	1.13 (5.50)	0.21 (0.35)	0.32 (3.20)	1.05 (6.00)	24.00 (5.60)
Nuclear	0.85 (1.60)	—	—	—	—	21.50 (5.00)
Natural gas	—	—	2.30 (3.80)	—	0.25 (1.43)	25.70 (6.00)
Geothermal	—	0.85 (4.10)	—	—	—	0.43 (0.10)
Others	2.90 (5.40)	6.70 (32.70)	36.47 (60.40)	0.24 (2.40)	3.71 (21.20)	0.87 (0.20)
Total	53.45 (100.00)	20.50 (100.00)	60.40 (100.00)	9.88 (100.00)	17.49 (100.00)	429.00 (100.00)

[a] 5th five-year plan's supply-demand program adjusted (Sept. 1982), Power Resources Div., the Republic of Korea.
[b] The National Energy Program 1981-86.
[c] 3rd five-year plan, the Republic of Indonesia.
[d] An introduction to Malaysia's Energy Sector (May 1982) Kementerian Tenaga, Telekom & Pos.
[e] Thailand Energy Situation 1981-82.
[f] Revised long-term energy supply-demand forecast (April, 1982).

TABLE 3 - *Energy Demand Forecasts for South-east Asian Countries.*

(Unit: million $k\ell$ oil equivalent)

	South Korea [a] (1986)	Philippines [b] (1986)	Indonesia [c] (1984)	Malaysia [d] (1985)	Thailand [e] (1986)	Japan [f] (1990)
Oil	33.20 (46.20)	8.96 (32.90)	37.13 (79.00)		9.91 (45.80)	289.70 (49.10)
Coal	27.60 (38.50)	4.07 (15.00)	1.13 (2.40)		1.97 (9.10)	115.00 (19.50)
Hydro	0.86 (1.20)	2.55 (9.40)	0.98 (2.10)		1.67 (7.70)	29.50 (5.00)
Nuclear	7.50 (10.50)	0.89 (3.30)	—		—	66.70 (11.30)
Natural gas	—	—	7.72 (16.50)		4.00 (18.50)	67.90 (11.50)
Geothermal	—	2.65 (9.70)	0.01 (0.03)		—	5.90 (1.00)
Others	2.60 (3.60)	8.07 (29.70)	—		4.11 (18.90)	14.80 (2.50)
Total	71.80 (100.00)	27.20 (100.00)	47.00 (100.00)	14.4**(100.00)	21.66 (100.00)	590.00 (100.00)

* The 3rd five-year plan mapped out a long-term plan for only commercial energy. Consumption of non-commercial energy, such as woods and agricultural wastes, which is predicted to account for around 60% in the table, is not necessarily grasped exactly.

** Demand forecasts by energy source are not available.

[a] 5th five-year plan's supply-demand program adjusted (Sept. 1982), Power Resources Div., the Republic of Korea.

[b] The National Energy Program 1981-86.

[c] 3rd five-year plan, the Republic of Indonesia.

[d] An introduction to Malaysia's Energy Sector (May 1982) Kementerian Tenaga, Telekom & Pos.

[e] Thailand Energy Situation 1981-82.

[f] Revised long-term energy supply-demand forecast (April, 1982).

as valuable earners of foreign currency. While all of the five countries are oriented toward conversion to coal, situations of other alternative energies vary depending on countries.

South Korea, with limited energy resources, where significant progress has already been made in coal conversion, plans to boost weight of nuclear power, while further promoting coal conversion. In addition to coal, the Philippines aim at conversion to hydro, geothermal and nuclear power. Indonesia and Thailand place special emphasis on conversion to natural gas abundant in these countries. Though not disclosing detailed plans, Malaysia also seems to move toward conversion to natural gas available in the country in large quantities.

Tables 3 and 4 contain power generation by energy source at present and in the future, respectively. Electricity generation of all the five countries is incomparably lower than Japan's, even South Korea generates as little as 40,000 GWh, which is equal to only about 8% of Japan's electricity.

In general, dependence on oil-fired (incl. diesel) power generation is high, although situations are different in the Philippines and Thailand, with the former showing a marked ratio of geothermal power generation and the latter of gas-fired power generation.

Looking at power demand forecasts, as usual in developing countries, rates of growth predicted for these countries are as sharp as more than double without an exception. The predicted growth rates are: 2.8 times (1991/1981) for South Korea, 2.2 times (1990/1981) for the Philippines, about 5 times (1989/1981) for Indonesia, 2.8 times (1990/1980) for Malaysia, and about 2 times (1990/1982) for Thailand. In comparison, Japan's power demand is forecast to grow 1.6 times (1990/1980).

To meet growing demand, South Korea concentrates on introduction of much larger nuclear power generating capacity (52.1% to total generated output by 1991), while endeavoring to promote conversion to coal-fired and LNG-fired power generation. The Philippines entertain particularly great hopes on geothermal power generation, with coal and nuclear power planned to bear appropriate shares. Indonesia has large-scale hydro plans in such places as Asahan in North Sumatra and Saguling in West Java, while aiming at conversion to coal abundant in the country. In Malaysia and Thailand, conversion to natural gas will form their principal measures as mentioned before.

Sooner or later, fossil fuels will be drained (some say that even Indonesia will turn to be an oil importer at the beginning of the next

TABLE 4 - *Generated Output by Energy Source in South-east Asian Countries.*

(Units: GWh, % for figures in parentheses)

	South Korea [a] (1981)	Philippines [b] (1981)	Indonesia [c] (1980/81)	Malaysia [d] (1980)	Thailand [e] (1982)	Japan [f] (1980)
	GWh	GWh	GWh	GWh	GWh	GWh
Hydro	2,694 (6.7)	3,627 (23)	1,345.4 (18)	1,274.0 (14)	4,356 (21.7)	85,100 (16.6)
Coal	2,533 (6.3)	—	—	—	1,777 (8.8)	22,700 (4.4)
Oil (incl. diesel)	32,085 (79.8)	9,304 (59)	5,105.0 (68)	7,446.3 (83)	5,075 (25.3)	226,000 (44.0)
Gas	—	—	1,050.4 (14)	303.8 (3)	8,882 (44.2)	97,400 (18.9)
Geothermal	—	2,838 (18)	—	—	—	900 (0.2)
Nuclear	2,895 (7.2)	—	—	—	—	82,000 (16.0)
	GWh	GWh*	GWh**	GWh	GWh	GWh
Total	40,207 (100.0)	15,770 (100)	7,501.9 (100)	9,024.0 (100)	20,090 (100.0)	514,100 (100.0)

* The figure covers only generated output by the Philippine Electric Power Corporation (NPC). An additional generated output of about 15% is available from non-NPC sources.

** The figure covers only generated output by the Indonesian Electric Power Corporation (PLN). Generated output from non-PLN sources is estimated to be the same as PLN's. In 1979/80, the PLN accounted for 54% of the country's total generating capacity, while non-PLN sources 46%.

[a] Electric Power in Korea 1982 KEPCO.
[b] 1981 Annual Report NAPCO.
[c] Electric Supply by PLN in Indonesia 1980/81.
[d] 31st Annual Report 1980.
[e] EGAT Power Development Plan (1982-1996).
[f] Revised long-term energy supply-demand forecast (April, 1982).

TABLE 5 - *Generated Output Forecasts by Energy Source in South-east Asian Countries.*

(Units: GWh, % for figures in parentheses)

	South Korea [a] (1991)	Philippines [b] (1990)	Indonesia [c] (1988/89)	Malaysia [d] (1990)	Thailand [e] (1990)	Japan [f] (1990)
	GWh	GWh	GWh	GWh	GWh	GWh
Hydro	3,772 (3.3)	9,688 (28)	10,000 (27.0)	6,061 (24)	7,409 (18.3)	107,000 (12.7)
Coal	25,836 (22.6)	4,498 (13)	10,000 (27.0)	—	9,657 (23.8)	104,000 (12.4)
Oil (incl. diesel)	11,660 (10.2)	6,228 (18)	16,000 (43.2)	7,071 (28)	4,550 (11.3)	148,000 (17.6)
Gas	13,489 (11.8)	—		12,122 (48)	18,880 (46.6)	210,000 (25.0)
Geothermal	—	10,380 (30)	1,000 (2.8)	—	—	18,000 (2.1)
Nuclear	59,559 (52.1)	3,806 (11)	—	—	—	253,000 (30.1)
	GWh	GWh*	GWh**	GWh	GWh	GWh
Total	114,317 (100.0)	34,600 (100)	37,000 (100.0)	25,255 (100)	40,496 (100.0)	840,000 (100.0)

* The figure covers predicted generated output only for NPC.
** The figure covers predicted generated output only for PLN.
[a] Electric Power in Korea 1982 KEPCO.
[b] 1981 Annual Report NAPCO.
[c] 4th five-year plan, the Republic of Indonesia.
[d] 31st Annual Report 1980.
[e] EGAT Power Development Plan (1982-1996).
[f] Revised long-term energy supply-demand forecast (April, 1982).

century), therefore it is common to these countries that they are required to take measures in preparation for changing situations.

2. *Review of Alternative Energy Development in South-East Asia*

During the past decade, the environment of energy problems has greatly changed with the two oil crises as turning points. That is, the oil crises triggered sharp oil price increases followed by worldwide recessions and developments of alternative energy resources, resulting in the urge for oil producing countries to cut their crude oil prices as well as the amount of export. These structural changes in oil supply-demand and prices have naturally produced great impacts on national alternative energy development policies throughout the world.

In particular, development plans of synthetic fuel, from coal through gasification and liquefaction, which have brilliantly started after the first oil crisis under the initiative taken by Japan, the United States and West Europe, are recently exposed to a severe trial because of surplus and price decrease of crude oil.

However, during the past decade, conventional alternative energies, including coal, natural gas and nuclear power, have constantly expanded their shares in primary energy, thus greatly contributing to save oil consumption.

On the other hand, alternative energy development in developing countries has various aspects different from development plans designed for advanced countries. In other words, alternative energy development in developing countries should not merely pursue introduction of energy sources to substitute for oil but be closely related to their industrialization plans.

This means the need to promote industries, expand employment and improve income levels through energy development.

Energy development in LDCs is generally planned by taking into account national or regional development. In other words, energy development is expected to contribute to the development of a given LDC by creating exportable energies and/or industrial products derived from such energies. Also, energy development can be expected as a measure to reduce oil imports of a given LDC whose financial situations have acceleratedly been worsening due to sharply increasing energy prices.

Although the majority of energy-related giant projects fall in the former case, aiming at creation of exportable energies and/or industrial products, many of them have difficulties, including availability of markets, particularly amid the prolonged recession of the world economy. Second, many of these giant projects require highly sophisticated technologies and huge investments, which often must be offered by developed countries or international organizations. Once in operation, such projects can reveal resource-plundering situations. Despite improved cash income, which may be possible from such sources as royalties, the projects would fall short of a nation's expectations. In short, if the national interest of the broader general public is not well considered, progress in such developments can produce deteriorating effects to the nation in the long run. For example, it can produce adverse effects on the phases of the income distribution, social and natural environment and resources. In many LDCs, their assets are natural environment and natural resources. Once destroyed by giant projects or as projects or as a result of energy problems, their assets, or natural environment, are irrecoverable.

In other words, it seems that there are two cases; one is that energy problems contribute to the development of LDCs, and the other is that they arrest the development.

Considering that what a nation or a region wants to have is reflected in its policy, any plans of development should be in harmony with communities and nature involved. Creation of permanent jobs is more significant than an offer of temporary construction jobs. In this light, job-creating projects, such as biomass-based energy development, are highly potential. With biomass-based energy development combined with food production, energies are produced from surplus farm products as well as agricultural wastes, which are primarily used by local people to improve their living standard. Surplus energy, if any, can be exported outside the region. Ethanol production from such sugar-containing crops as sugar cane as well as starch-containing crops including potatoes through fermentation has already been in practice in Brazil and part of the United States. Projects of this kind seem to show a direction to be taken by many LDCs, particularly non-oil LDCs, blessed with natural environment. Japan, making continuous efforts for R&D on fuel alcohol production technologies based on existing alcohol fermentation technologies, has been offering technical cooperation in this field to several countries.

Meanwhile, excessive drifts of population to cities are forming big problems in LDCs. Job-creating energy development to promote the development of local communities can help LDCs solve the problems, because they lead to moves of people from densely populated cities to local rural areas.

Likewise, introduction of power sources of dispersive type deserves to be given consideration. Although fairly large-size power sources, such as coal and nuclear power, are considered to be fit for the needs of expanding cities, they currently have problems to be solved, particularly problems related to their operation. Hence, recommended is introduction of small-, medium-size power sources of dispersive type which can cope with size and fluctuations in demand in individual comunities. At present, diesel engines serve as the major power source of the type, while gas turbines, particularly those of methanol reforming type, fuel cells and photovoltaic cells are high potential. Some of them discharge warm effluents, which can be effectively used in combination with light industries or applied to such fields as food processing.

I like to introduce the following two projects of alternative energy developments just as only a few examples of international cooperation in these respects. The examples are international cooperation between Japan and Indonesia, and one is related to biomass and the other is brown coal.

Among national programs, given priorities by the Indonesian Government are to develop alternative energies, to promote the transmigration and to develop industries. And South Sumatra is nominated as one of the most prospective sites for the transmigration from Java where almost 70% of the Indonesian population is concentrated.

The Biomass Energy Research and Development Center was constructed in Sulusuban of South Sumatra in March, 1983, in accordance with the Indonesian National Alcohol Supply Program. The basic concept is that the Center should be a practical one for development of applied technology concerning fuel alcohol rather than an academic one. Therefore, the center is composed of an experimental alcohol plant (8kℓ/day), research laboratory and an experimental farm. The site has a total area of about 50ha of which 10ha is allotted to a sweet potato experimental farm. Cassava and sweet potatoes are feed for the alcohol plant.

In the area, there are cassava plantations some of which are joint ventures of Japanese and local businesses.

Of the funds required, the Japanese government provided some ¥1.6 billion and the Indonesian government some ¥500 million.

Assuming expansion of planting area and increasing of productivity of cassava, the potential surplus of cassava will amount to 11.5 million

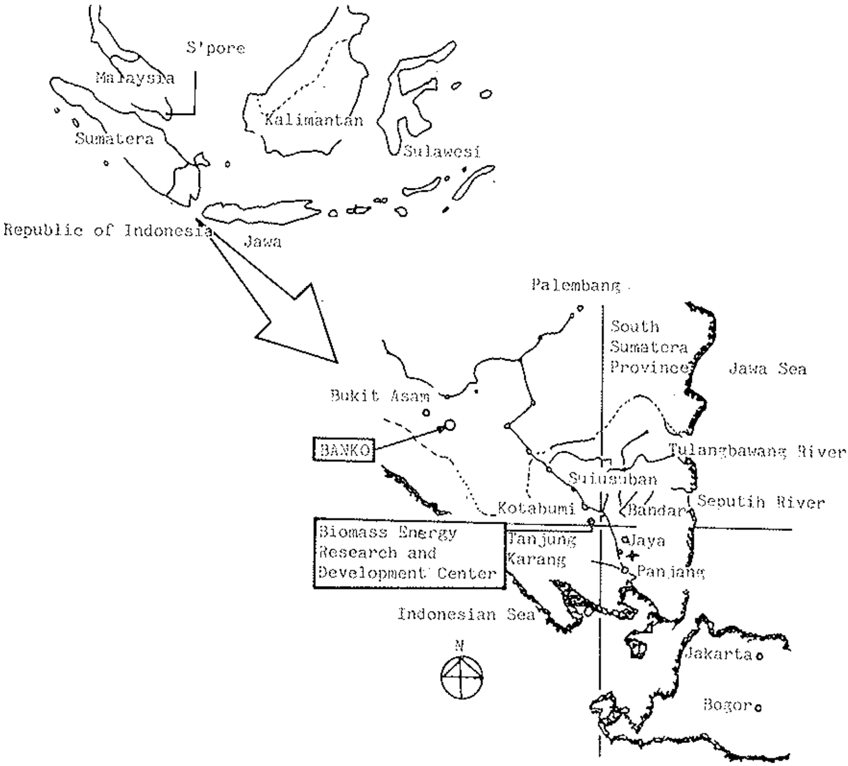


FIG. 1. Location map of Biomass Energy Research and Development Center and Banko.

tonnes or 12 million tonnes in 1990 and 19 million tonnes — 20 million tonnes in 1995. Potential volume of alcohol supply, which is calculated based on above figures in 1990 and 1995, will reach 2.1 million kℓ and 3.7 million kℓ to 4 million kℓ in 1995 respectively.

On the other hand, motor gasoline consumption in 1980 was 3.8 million kℓ per annum. We, now, assumed that the growth rate of gasoline demand will increase by 7% per annum up to 1990 and by 8.7% from 1990 to 1995 in accordance with the low case of energy forecast made by the government. The gasoline demand in the forecast will reach 7.5 million kℓ in 1990 and 11.5 million kℓ in 1995 respectively.

If the prospected gasoline demand could be replaced by or mixed with alcohol up to 10%, requirement for alcohol will account for 750 thousand kℓ in 1990 and 1.15 million kℓ in 1995 respectively.

As mentioned above, Indonesia has a great potentiality to produce alcohol from surplus crops, so that, if this alcohol production program is promoted smoothly, it may contribute to the nation's future energy supply. (Table 6)

Here we assume that the standard size of local fuel alcohol plant is to be around 5,000 kℓ/year, which is relatively small. Because 1ℓ of ethanol needs about 6 kg of cassava, the plant consumes about 30,000 t/year of cassava. Again we assume that 10 t/year of cassava can be produced by one farming family of five members. 3,000 farming families consisting of 15,000 members are able to produce 30,000 t/year of cassava.

In 1980, motor gasoline of 3.8 million kℓ was consumed in Indonesia. If we assume five percent of that amount can be replaced by ethanol, we need 190 thousand kℓ of ethanol, 1.14 million tonnes of cassava, 38 alcohol plants of 5,000 kℓ/year and, 114,000 farming families of 570,000 people.

In this way, the National Alcohol Supply Program is closely related to the transmigration program.

As an important alternative energy source, coal is expected to have a growing demand in Indonesia. In particular, coal use as power generation fuel is assured to grow with the start-up of thermal power plants in Sulalaya and other areas. Coal use in the cement industry is also

TABLE 6 - *Potential Alcohol Supply from the viewpoint of Raw Material Production in Indonesia.*

	1990		1995	
	surplus agricultural products	alcohol equivalent	surplus agricultural products	alcohol equivalent
	(1,000 t)	(1,000 kℓ)	(1,000 t)	(1,000 kℓ)
Cassava	11,100 ~ 11,500	2,000 ~ 1,900	19,400 ~ 19,700	3,200 ~ 3,300
Sweet potato	700 ~ 1,400	100 ~ 200	3,100 ~ 4,000	500 ~ 700
Sugarcane	non surplus	——	non surplus	——
Total		2,100		3,700 ~ 4,000

expected to increase gradually in the coming years. On the other hand, some 200,000 tonnes of coal is currently supplied each year from Ombline and Bukit Asam mines, the former situated in Central Sumatra and the latter in South Sumatra. To deal with the expected growth of demand, the government is now carrying on output expansion programs at both mines. In addition, coal development in Kalimantan is just getting under way, thus expected to serve as a new supply source in the future.

From the long-term viewpoint, diversified coal uses include coal gasification and synthetic gas to supply chemical feedstocks, methanol, etc. Particularly promising is gasification-based effective utilization of low-grade coal (characterized by higher moisture content and lower calorific value than steaming coal and having a risk of spontaneous ignition which makes transport and storage difficult), such as Banko brown coal abundant in South Sumatra. The assured reserve of Banko coal is said to be about 400 million tonnes, and with ultimate reserve can reach 15 billion tonnes.

As described in the figure, synthetic fuel and basic chemicals such as methanol, gasoline, kerosene, gas, oil and urea can be produced by coal gasification and synthesis of produced gas from a technical point of view.

The feasibility of the project seems to be closely related to the market trend of the products in Indonesia and/or the area and many other factors, one of which is the transmigration program and infrastructure development plan of South Sumatra.

The related feasibility study including the transfer of technology relating to coal gasification has just started between the Japanese and Indonesian governments, and will last for five years. This project includes the construction of bench-scale coal gasification plant in PUSPIPTEK which is the national science and technology research center under construction in the suburbs of Jakarta. The five-year program will cost more than one billion yen for Japan, and this is based on the technology assistance policy of the Japanese government to provide alternative and new energy technology to developing countries.

Conclusion

1. Although the Asian Pacific Basin is believed to have higher potential of development than the other areas of the world, giant projects which aim at only exportable primary products should be reexamined mostly in the light of their market size and trends.

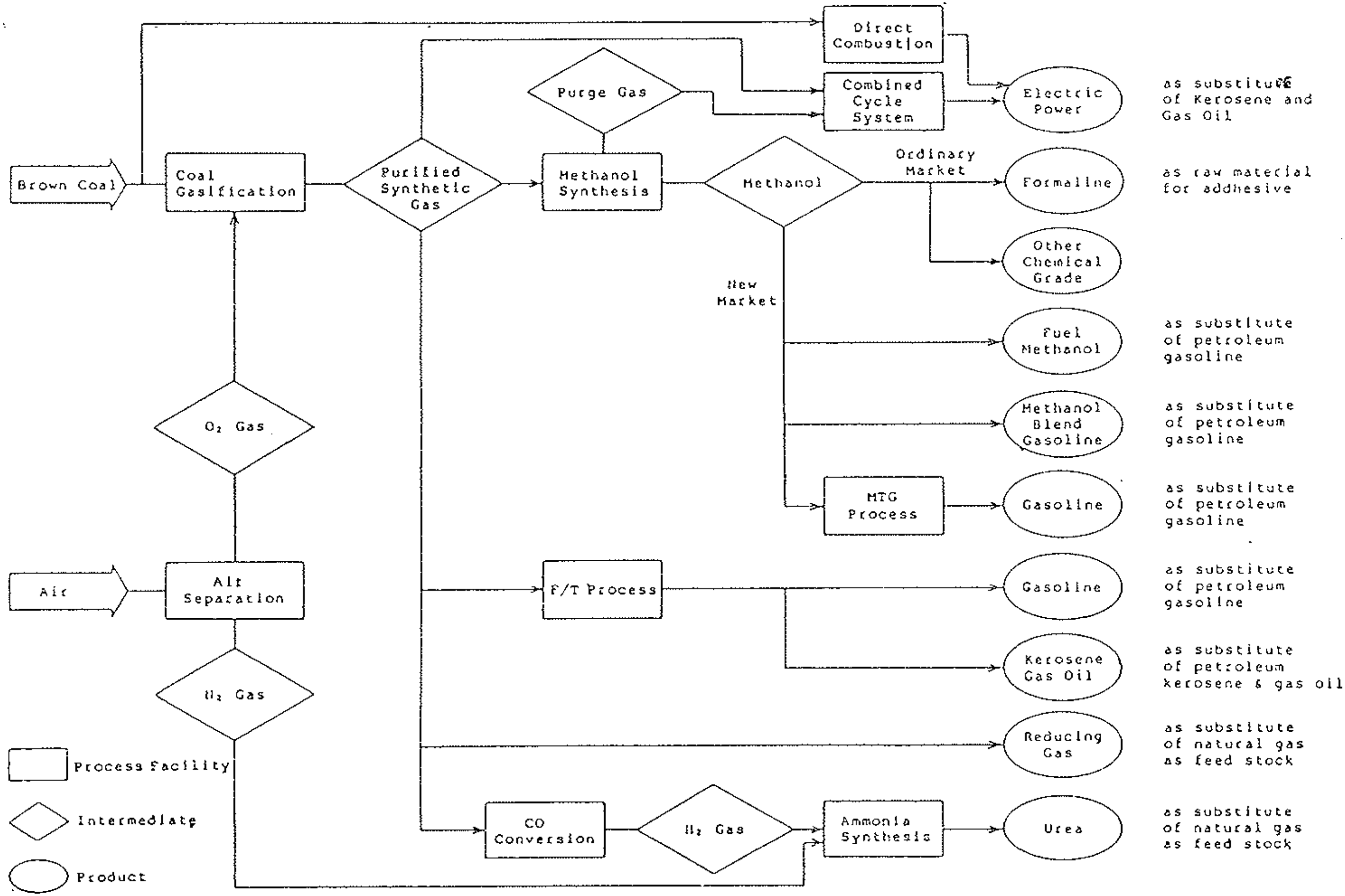


FIG. 2. Preliminary flow scheme for brown coal utilization.

2. In the above mentioned scope, many of the energy development programs should be reconsidered for their scale and schedule according to world energy demand growth.

3. However, once an energy development program is linked to domestic industrialization with adequate size of employment and technology transfer through proper planning effort, it will regain its attractiveness.

Primary energy and product should be processed as far as possible in the region to obtain as many hands on it as possible, mainly to secure employment and job-training. Through this process, part of energy and product would be consumed domestically and the other part for export. Therefore, new types of international framework for division of works should be studied and constructed.

4. Lead time for new energy development is to be relatively long, therefore a development program requires proper and adequate planning with a long-range perspective of the country and the region.

ACKNOWLEDGEMENT

The authors wish to thank Mr. Y. Hara, Institute of Energy Economics and Mr. H. Shozawa Industrial Research Institute, Japan, for many kind suggestions.

THE FOSSIL FUELS DEVELOPMENT: THE TUNISIAN EXPERIENCE

BOUBAKER LEMKECHER
Ministry of National Economy
Tunisia

Since independence, Tunisia has strongly encouraged hydrocarbon exploration with a view to meeting the country's needs and developing its natural resources. Many foreign companies have been encouraged to explore the country's subsurface. This encouragement has resulted in an extension of the area under exploration which has increased from 110,000 sq. km. in the early sixties to 160,000 sq. km. at present including all the potentially favourable areas. The number of permits has increased from 15 in the early sixties to more than 30 at present, with approximately 35 oil companies present.

Efforts in exploration have run parallel to the enlargement of this area, since investment in exploration in the late seventies was about 150 MD. per annum (210 M $ per annum) with an average of 20 to 25 wells drilled, as against 5 MD. per annum and 5 wells drilled in 1960.

The results of these efforts have been rewarding, since hydrocarbon production started in 1966 and is now about 6 MT. per annum: 5.5 MT. oil (92%) and 0.5 MT natural gas (8%).

In the meantime, internal consumpiton of energy, which at independence was 600,000 TEP. per annum, is now more than 3 MTEP. per annum, a very high rate of increase, at a time when production is stagnating; the ratio production/consumption was 4 during the early 70's, and is now 2 in the early 80's.

There are many reasons for this stagnation and this worries us as much as our partners. In fact, there is no lack of discoveries as about thirty petroleum and gas discoveries have been recorded, totalling about 210 M tons of initial recoverable reserves, comprising 155 M tons of petroleum and 55 M tons of natural gas. A historical analysis of the discoveries according to size and nature shows that, apart from the two major discoveries (El Borma and Ashtart) all those made over the last ten years have been marginal or small size fields.

As regards natural gas, and in spite of the lack of eagerness on the part of the companies, there are indications that a large potential exists which ought to receive more attention.

For Tunisia, these are not negligible discoveries and the fact that they are not developed by the companies leads us to think that the companies might in the future neglect the small structures, in favour of concentrating their efforts on the large ones. We are in fact looking closely at this problem, it being a vital and essential one for us in that it affects our future with regard to energy. Indeed, Tunisian energy consumption, apart from the traditional use of charcoal (charcoal = biomass?), is 100% dependent on petroleum and gas. Even if the use of coal to produce energy is nonexistent, the use of nuclear power cannot yet be justified (we have an upper limit of 150 Mg watts, whereas the point at which a nuclear power station becomes economically viable is 600 Mg watts), and efforts made in the realm of renewable energy can only produce limited results. Our virtually total dependence on hydrocarbons is therefore an important factor, so much the more in that petroleum has led to notable surpluses for export and has greatly contributed to reduce the deficit in the country's external finances, and for the state constituted an important income which is constantly being diminished as the years go by.

Among the themes proposed by this conference is that of the difficulties faced by the LDCs in order to exploit their fossil energy resources. We wish to share with you our thoughts on Tunisia's problems in developing small discoveries and gas discoveries, and we hope that the solutions we have reached will be of interest to other countries in a similar situation.

Given the importance of the problem, every specialized organization is paying attention to this matter.

Example: Let us take the real example of an oil company holding an exploration permit, who has made two on-shore discoveries after investing 60 M $ in exploration. The total output of the two discovery wells is not more than 2000 b/per day and the life expectancy of the fields is estimated between 2 and 5 years. Development would require an investment of at least 8 M $ and could reach 20 M $ according to the number of wells to be drilled and the results obtained. If these fields were put into production the pessimistic results would be an accumulated turnover of about 42 M $ (at a rate of 29 $ per barrel) and a cash flow of 39 M $. Optimistically, the results would be a turnover of 104 M $ with a gross cash flow of 96 M $, which appears to be rather interesting. But, in fact, taking into account the 15% royalties and the 65% petroleum tax, and adding to this the risk that development costs might reach the higher level, the probability that production will not reach the level anticipated, and finally, the fact that the pay back is spread over a period, it is understandable why the oil company is so hesitant to develop.

The agreements stipulate that the oil company alone bears the risk of research. So, in taking up the option to participate, the State company acknowledges a debt of 30.6 M $ (51% of 60 M $) to be reimbursed over 3 years, out of its share of the crude oil, and must also meet 51% of all the development costs. The gross cash flow anticipated by the national company over the first 3 years is 26 M $ which is not enough to reimburse its debts. There is therefore a very delicate decision to be made, all the more so in that production capacity of these discoveries is uncertain, in view of the lack of dependable technical information available at that time.

Therefore when it comes to developing the discovery, everyone is hesitant:

— The overseas oil company, which needs cash money, would like the national company to participate in order to spread the risks and ensure reimbursement of half the exploration costs already expended on the entire permit.

— On the other hand, the national company, having structural financing problems, does not have the means to undertake such high risks, even though it has the most to gain by the development of these structures and in ensuring the security of local supply.

So, we are faced with a discovery which requires only 8 M $ to be developed, and which would generate a gross cash flow of between 39 and 96 M $, and yet both sides hesitate. And for a number of reasons:

— Firstly, production is uncertain in view of the lack of technical information available, and in order to know more, more wells must be drilled, more seismic recorded and more studies made, which only increases the financial risk on a potentially small structure.

— Because the company has to pay tax and royalties before recouping its outlay.

— The national company's financial resources are poor, and therefore it is more vulnerable to any risk.

— Finally, according to the terms of agreement, the national company not only has to contribute to the cost of development as soon as the option to participate is taken up, but must also undertake to pay 51% of all exploration costs already expended on the whole permit.

To find a way out of this dilemma, we must be apprehensive of the problems. Indeed, for these small fields, attitudes on both sides must change. Aside from the customary rules concerning exportable resources, we must define and set up special rules for these categories (small size fields and gas fields). For the overseas company, the objective will be to have an acceptable and sufficient return (possibly a financial interest only). For the local conceding authority, the goal is to guarantee supply at a reasonable cost, and to put these resources to use for the development of the country.

The adaption and incentive measures would include:

(1) Financing: for the small fields, investment is relatively high. Therefore, in the interests of the country and with a view to lightening the burden on the oil companies, local participation is necessary. In spite of the lack of funds at the countries' disposal, they cannot do without participating in these projects. Therefore, financial aid on the part of international finance organisations such as the World Bank is urgently needed to help the state company participate and pay its share within a system of appropriate and sufficiently staggered loans.

(2) In order that the reimbursement of the granted loans be guaranteed, the organisation must take care that the country remains sufficiently affluent to meet its debts. Consequently and in view of the fact that for political, economic and social reasons, petroleum products are sold on the local market at very low fixed prices, the financing organisations must negotiate prices with the authority concerned that are near the cost price (economical cost) and try to determine a means of indexation based on international mechanisms which reflect international market conditions and are independent of the two contracting parties.

(3) Enable the international company to be assured of an adequate, even accelerated, amortization by devoting, for example, the cash flow over the first few years to recoup the outlay.

(4) Fiscal laws must be moderated and modulated according to the size of the fields and production capacity, or even according to the profitability of the project. The country concerned must consider these resources to be developed for local market needs, much more as a guarantee of the security of supply at reasonable cost, than as a means to getting a quick return on investment.

(5) Authorize the company to amortise its investments in other discoveries in the same permit or even possibly in other permits.

(6) Since in a great number of contracts and agreements the oil companies have long term rights over these discoveries even if they are not interested in developing them, we must bring in the idea of transferring the so-called marginal discovery to the national company, against adequate compensation. This measure would by its nature induce the oil companies not to "freeze" certain marginal fields or gas fields.

Special measures for natural gas

The first step we need to take to encourage the exploration and production of natural gas is to develop down stream activities, that is to build up an active and receptive local market by giving priority to gas over other forms of energy, by developing an extensive transport and distribution network and by avoiding saturating the market with fixed long term import contracts.

Then the commercial framework, which is to regulate the production and transfer of gas on to the local market, must be specified. Here, there are two determining parameters. On one hand, the transfer price of the gas must be sufficiently profitable and must be indexed to substituting forms of energy. On the other hand, there are the lifting guarantees to be given to the producers, in the form of "take or pay" or other equivalent formulas.

In view of the medium and long term energy perspectives, pricing of the gas at the production stage could be based on the international price of heavy fuel, which in the medium term is the most frequent form of substitute energy.

As for the guaranted outlets this could be given in the form of "take or pay" based on the permanent financial requirements of the producers.

An appropriate fiscal framework must also be defined. Indeed, because of the weight of investment involved and the fact that it has a lower profitability than oil, natural gas necessitates relatively moderate taxation as regards the proportional royalties as well as the tax or profits. In this respect, progressive taxation in installments based on annual production and according to the location of the field (on-shore, off-shore) could be applied to gas.

Furthermore, a simplified exchange procedure should be applied to the profits from gas, being motivating for foreign investers, with in particular a relatively speedy transfer of profits.

Finally, there is a serious risk of disagreement between the Companies and the Granting Authority on the development of gas discoveries for the local market. Therefore, a procedure must be set up to transfer these discoveries to the Granting Authority against payment of adequate compensation to the companies. This compensation could have its effect on the reimbursement of the costs of the exploration which led to the discovery, by deduction on production or profits during exploitation.

To sum up, we wanted to outline some new measures to be added to all the positive factors which have already produced results, one of these factors being the creation of a politically and economically stable framework for foreign investment.

Furthermore, our approach in negotiating contracts is not rigid and leaves room to determine conditions to suit each permit and each company, with a flexible system of exchange rates and a variety of formulas for partnerships and organisations.

UTILIZATION OF HYDRO RESOURCES IN DEVELOPING COUNTRIES

ARNALDO M. ANGELINI
Emeritus Professor of the University of Rome

Foreword and synopsis

This paper deals with the problem of using hydroelectric resources that exist, still untapped, in a number of Third World countries.

I have had occasion in the past to emphasize the fact that, according to the World Energy Conference's estimates, these untapped resources are enormous, with an annual technically exploitable producibility of not less than 10,000 billion kWh. (To give you some idea of what this figure represents, let me tell you that Italy's overall annual electric power requirement is about 200 billion kWh).

I hardly need to remind you that this enormous amount of energy is being irretrievably lost (since, from a thermodynamic point of view, it is degradation without utilization, with a corresponding irreversible increase in entropy). This is happening at a time when conserving non-renewable energy sources, that is to say fossil fuels and particularly petroleum, which is a vital and irreplaceable raw material for certain sectors of the chemical industry, transport etc., is becoming an acutely serious problem.

No less relevant is the fact that if this energy were to be utilized, it would give a major boost to the economic and social development of those countries which possess such an endlessly renewable resource.

In this paper, I shall be addressing several essential points showing that it is possible to hasten the utilization of the hydro resources in the developing countries, as I did at the 1974 World Energy Conference in Detroit.

As we shall see, the solution to these problems presents considerable difficulties, particularly in relation to their social and political implications.

International cooperation, not only between the Third World countries themselves (particularly those in the same continent), but also between them and the industrial countries, is the only way in which we can hope to find solutions to the problems dealt with in this paper.

I felt that this aspect should be given special emphasis at this particular seminar, because ever since his election to the See of Peter, the Holy Father has never tired of urging international cooperation, which is indispensable in such a vital sector as energy.

May I now summarize the possibilities that exist today to foster international cooperation to attain the objective with which this paper is dealing:

— it is in the interest of the industrial countries to relocate their energy-intensive manufacturing facilities in countries which have a ready supply of cheap energy;

— it is in the interest of the less advanced countries to hasten their industrial development by cooperating with the industrial countries, and by acquiring availability of their own indigenous energy supplies, particularly such a valuable energy form as electricity;

— the less advanced countries have already felt the need to give priority to developing hydroelectric power, as evidenced by the fact that they have increased their hydroelectric power output almost sixfold over the past twenty years;

— the industrial countries have been deeply involved in the construction of the existing hydroelectric facilities and in the projects now being implemented in developing countries.

These interests and spontaneous market trends can be brought even more closely together, and lead to even closer cooperation in the future.

This cooperation now has to be stepped up and broadened, and a greater trust must be established between the developing countries, and between them and the industrial countries, to enhance cooperation to the level required to hasten the hydroelectric power utilization and other programmes.

The contribution of hydro resources to meeting The Third World Energy Requirements

Hydro energy utilization is one of the most important indications that emerged from the 1981 United Nations Conference in Nairobi on "New and Renewable Sources of Energy". That Conference remains one of the major benchmarks even today when considering the most effective means of solving the energy problems of the developing countries. One of the aims of the Conference was to identify a policy for the optimum management of energy resources, to eliminate the uncertainties surrounding energy supplies and distribution. Accordingly, the General Assembly of the United Nations recommended that the Conference should devote itself to analyzing the status of techniques relating to new and renewable energy sources, to see how these sources could be used in the developing countries, to promote the exchange of information on all the aspects of the problems, and to identify the measures needed to transfer the techniques and assure financing.

These are the objectives that emerged from the official statements that also recommended that measures be taken at the national and international level to exploit the following energy sources: hydroelectric power, firewood, charcoal, biomass, solar energy, geothermal energy, wind power, schists, and bituminous and asphalt sand, wave power, draft animal power and peat.

The Nairobi Conference therefore had the merit, and the objective, of systematically organizing and suggesting ways and means of dealing with the developing countries' energy problems, emphasizing the need to hasten the utilization of the energy resources available in each country, *giving precedence to the convertible sources under the most economical conditions using established techniques.*

Hydraulic energy for the production of electricity is the first of these energy sources. Many developing countries possess a great potential as far as hydro resources are concerned, with a global production capacity that far exceeds that of the other renewable energy sources that are currently being studied.

The reasons for attributing priority to hydraulic energy over all the others listed above, apart from the fact that it is more abundant, are as follows:

— it is renewable *ad infinitum* and can be accumulated in reservoirs so that production can be adapted to consumption without losses;

— it offers the country the maximum guarantee of continuity of energy supplies and energy independence, just as it did in many countries until the middle of the present century, when "white coal" (as hydroelectric energy used to be called) met all their electricity requirements;

— hydroelectric power, through accumulation in reservoirs using pumping stations, is also the most cost-effective and the soundest regulator of other energy sources, particularly those which, by their very nature, change over time, such as solar energy, wind power, wave power, etc.

Moreover, the production of hydroelectricity:

— is based on well established techniques and technologies with almost a century of experience behind them;

— is wholly "clean" in the production phase, because totally pollution-free.

It was with this in mind that the Nairobi "Plan of Action" was drafted, stating that hydroelectric power was a matter of priority because of its enormous technically and economically viable energy potential, particularly in the developing countries, and because the technologies available are fully mature.

Not all the countries generally labelled as "developing" are equally well-endowed with hydro resources; they include countries in Africa, Asia, and Latin America which differ widely in their social systems, objectives, and their human and physical resources.

The following table (Table 1) gives the structure of the world consumption of primary energy resources in the major geo-economic areas in 1960 and 1978 (the latest year for which such exhaustive statistics are available). It shows that in the *Third World* countries (Centrally Planned Asian Countries and Developing Countries):

— non-commercial energy sources (firewood, vegetable and animal waste) accounted for 37% of total consumption in 1978;

— hydro resource use rose more sharply than any other. Over the past 18 years it has grown fivefold, and between 1960 and 1978 it rose from 2.4% to 5.6% of total consumption. If one considers the developing countries alone, the growth rate has been even higher;

— in 1978, hydroelectricity accounted for a substantially higher share of the energy consumed in the developing countries (7.7%) than the aggregate world consumption (5.7%).

TABLE 1 - *World energy consumptions broken down by sources.*

(Million Tons of Oil Equivalent)

Geo-Economic Areas	Year	Fossil Fuels (Oil)		Hydro	Nuclear	Non Commerc. Energy/New Sources	Total
Market Economy Industrialized Countries	1960	1,751	(715)	133	—	83	1,967
	1978	3,264	(1,799)	254	131	70/2	3,721
Centrally Planned Industrialized Countries	1960	519	(125)	13	—	46	578
	1978	1,313	(404)	42	12	46	1,413
Centrally Planned Asian Countries	1960	138	(9)	4	—	148	290
	1978	405	(89)	14	—	219	638
Developing Countries	1960	176	(114)	14	—	283	473
	1978	556	(384)	81	3	400/6	1,046
World	1960	2,584	(963)	164	—	560	3,308
	1978	5,538	(2,676)	391	146	735/8	6,818

Table 2 shows the structure of energy consumption in various developing continental and subcontinental areas, and reveals the differing proportions of primary energy sources to meet aggregate demand in each case. Hydroelectricity varies from 2.3% in South-East Asia to 14.3% in Latin America.

A short digression on available energy trends

Until the end of the present century, at least, hydro power and nuclear power will be the most important sources of energy in terms of volume and in terms of the way they are replacing fossil fuels. And electricity is the only way in which either of these resources can be utilized. If the obstacles to the construction of nuclear power plants in several countries can be overcome in the short term, the world's aggregate nuclear installed capacity will be 600,000 MW, equivalent to an annual output of 3,500 billions of kWh.

The other power source is water, but the still exploitable potential in industrial countries is rather limited. The bulk of available water supplies is in some of the Third World countries, whose potential is around one million MW, with a corresponding producibility of about 10,000 billion kWh. Even though not all these resources can be cost-effectively exploited at the present time, one must acknowledge the fact that about one half of this energy potential is equivalent to the producibility of between 800 and 1,000 nuclear power stations, each having an installed capacity of 1,000 MW, and is even greater than the world nuclear energy output forecast for the year 2000.

Possibilities for cooperation between the industrial and the developing countries

What I have just said underlies the guidelines for cooperation between the industrial and developing countries that I announced at the 9th World Energy Conference in Detroit in 1974, which were put forward again at the Nairobi Conference, and which received much consensus at the 1982 Italo-African meeting in Rome on the future of hydroelectricity in Africa, and were illustrated yet again in June 1983 at the Dakar Seminar on "Focus on Energy in Africa". And it was a source

TABLE 2 - *Energy consumptions in developing countries in 1978, broken down by sources.*

(Million Tons of Oil Equivalent)

Developing Areas	Fossil Fuels (Oil)	Hydro	Nuclear	Non Commerc. Energy/New Sources	Total	Hydro/Total %
North Africa & Middle East	100 (79)	6	—	18	134	4.5
Sub-Saharan * Africa	21 (16)	6	—	96	123	4.9
(South Africa)	50 (11)	1	—	3	54	1.9
South Asia	82 (29)	13	1	118	214	6.1
South-East Asia	113 (92)	5	—	101	219	2.3
Latin America	230 (168)	51	2	67/6	356	14.3
Total Developing Countries *	556 (384)	81	3	400/6	1,046	7.7

* Excluding South Africa.

of great satisfaction to me to see that they were taken into consideration in some of the papers submitted at the World Energy Conference in New Delhi in September 1983.

What I said on those occasions, which has become even more topical by the events taking place at the present time, such as the very worrying situation in the Persian Gulf, might be summarized as follows: many developing countries have sufficient water resources to be able to produce electric power which could compete in price with the electricity produced by fossil fuels in most, if not all, of the industrial countries. In many instances, the availability of this energy is far superior to the forecast requirements even if one looks well beyond the medium term.

The areas in which plants could be built are mostly far removed from the consumption areas, where the energy requirements are still very low. This means that the bulk of the producible energy would remain unutilized unless industries are established as close as possible to the generating plants to produce energy-intensive products.

Furthermore, certain industrial countries, of which Italy is a very good example, will have to cut back on energy consumption because of the procrastination of the authorities in building new generating plants, which has been a source of complaint for many years now.

In such countries, where it takes eight to ten years from the issuance of all the licenses, to build a nuclear or conventional thermoelectric power station, the energy deficit is bound to increase as the demand for electricity outstrips the supply, which cannot rise above present levels. To alleviate this situation, one might reasonably expect the country to have to gradually phase out the production of energy-intensive products (which are not usually labour-intensive).

In addition to this, and apart from the comments I have just made, so long as oil (and to a lesser degree, coal) continues to be the main source of electric power, the products whose prices are largely determined by the cost of energy will become increasingly less competitive with those produced in countries that have comparatively cheaper energy, such as that which could be generated by hydro plants in several developing countries.

The countries that are poor in primary energy resources, where the price of electricity makes their energy-intensive products uncompetitive, will sooner or later have to give up these products and go in for low-energy products which are generally more sophisticated and more labour-intensive.

These general comments show that a good many developing countries have a clear possibility of embarking on industrial development, as the industrial structure of a fair number of industrial countries changes.

There is no doubt, as has been said on more than one occasion in the past, that developments of this kind raise many and significant problems.

Hydroelectric resource-use in the developing countries

As we have seen, hydroelectric resources have been developed considerably in the Third World countries over the past 20 years.

Despite this development, however, the utilization level of their hydroelectric potential is still very low, as Table 3 shows. This table gives the figures for the technically exploitable hydroelectric resources in the four geo-economic areas examined in this paper, and compares them to the total hydroelectric output in 1981. Even though not all the resources indicated are economically viable, one may reasonably expect hydroelectricity production to increase considerably over the coming years.

Table 4 is taken from a report published by the Conservation Commission of the World Energy Conference, and provides the forecast energy consumption figures for the years 2000 and 2020. In this table, the forecasts are given for the total consumption of primary sources, the

TABLE 3 - *Technically exploitable resources and hydroelectric production in* 1981.

Geo-Economic Areas	Technically Exploitable Resources	Hydro Production	Production in Percent of Resources
	Billion kWh		%
Market Economy Industrialized Countries	4,000	1,105	27.6
Centrally Planned Industrialized Countries	2,300	216	9.4
Centrally Planned Asian Countries	2,000	90	4.5
Developing Countries	10,700	373	3.5
World	19,000	1,784	9.4

TABLE 4 - *World energy consumption forecasts.*

(Million Tons of Oil Equivalent)

Geo-Economic Areas	Year	Hydro	Nuclear	Commercial Energy	Total Primary Sources
Market Economy	2000	349	645	5,194	5,356
Industrialized Countries	2020	412	1,314	7,170	7,348
Centrally Planned	2000	70	240	2,405	2,440
Industrialized Countries	2020	130	600	3,370	3,400
Centrally Planned	2000	50	7	859	1,063
Asian Countries	2020	150	30	1,360	1,440
Developing Countries	2000	239	85	2,362	2,895
	2020	667	354	5,167	5,769
World	2000	708	977	10,820	11,744
	2020	1,359	2,298	17,067	17,957

commercial energy sources alone, and the share of hydro and nuclear sources that can be converted practically only into electric power and which are the most viable energy sources as an alternative to oil.

These forecasts are based on the understanding that the countries will embark on the hoped-for path of cooperation, leading to "the desirable long-term image of a world in which, after the present crisis, economic growth will again reach levels in accordance with the common aspirations of the Less Developed Countries and the Industrial Countries" (*). They therefore reflect the slightly optimistic assumptions I envisaged a moment ago.

Without this complete cooperation, in the year 2000 the share of hydro resources will fall by 4.5% below the previous level in the industrial countries and by 23% in the Third World countries (developing countries and centrally planned Asian countries), which will find it more difficult to obtain the financial resources they need. The 23% fall will, however, be less than the decrease in consumption of commercial energy

(*) World Energy Conference - Conservation Commission. "Energy 2000-2020. World Prospects and Regional Stresses".

sources, which will be about 30%, only partially offset by the increase in non-commercial energy source consumption (+17%). If development falls short of the forecast levels, non-commercial sources will account for 28% of the Third World consumption, which is 9% more than the previous forecast.

In both instances, despite the difference in the actual values, in the year 2000 hydro resources will account for 7% of the Third World's aggregate energy consumption, rising to 11% by the year 2020, with a total contribution at this latter year of 2,200 billion and 3,500 billion kWh, in the high and low scenarios, respectively, which will be over one half of the world hydroelectric power output, forecast for that period. The corresponding development rates for hydro resources in the Third World countries will be quite high up to the year 2000, and even higher still between 2000 and 2020.

A climate of cooperation between the Third World and the industrial countries will foster the establishment of large hydroelectric installation with a highly favourable capital cost per installed kW.

The following Table (**), (Table 5), shows the capital costs for each type of electric power production plant. One can see from the table the low capital cost of the fuel-oil and diesel plants. Apart from the

TABLE 5 - *Comparative capital costs of generating capacity.*

Type of Plant	Capital Costs (1982) $/per kW
Oil Fired Thermal	750-1600
Diesel	800-1100
Natural Gas	700-1100
Coal Fired	1100-2000
Hydro > 20 MW	900-2500
Mini Hydro	2500-3500
Geothermal	2000-2500
Nuclear	1800-2800

(**) World Energy Conference - Conservation Commission. Report by the Oil Substitution Task Force: Oil Substitution. World outlook to 2020. New Delhi 1983.

fact that with hydroelectric plants there is no marginal cost for fuel, their operational simplicity, flexibility and energy-independence could make it viable to concentrate on developing large-scale utilization programmes for them.

What can be done to hasten the utilization of hydro resources in the developing countries.

Considering the energy scenario I have just described, and leaving aside for the moment all the eventual political problems, one could envisage the following concrete steps to hasten the utilization of the hydroelectric power resources in the developing countries:

— Energy-intensive plants could be built as close as possible to the most economical hydroelectric sources whose potential exceeds local demand. Once guarantees exist that supplies of raw materials for processing can be supplied economically, these plants could viably replace the obsolete plants in the industrial countries where low-cost energy is no longer available.

— The new thermoelectric plants should be restricted to the indispensable minimum, and preference should be given to high capacity-utilization hydroelectric plants to cover the base of the load curve, linked by means of very long very-high voltage lines, thereby fostering interconnection with the networks of distant countries.

— Diesel-fired units should be gradually replaced by long HV lines (66 kV-170 kV) to provide local power supplies, even though they would initially be under-utilized, because they would only distribute a small fraction of the surge impedance loading across distances that are typical of VHV lines. The diesel-fired units already in operation would remain as auxiliary plants to meet essential needs in case of line failure.

The last two measures would help to boost the production of hydroelectric power, both because the lower cost and the greater availability of power would encourage demand to rise by more than the 6% increase recorded in recent years, and also because the increase would be underpinned by particularly viable supplies from plants producing very low-cost electricity. The Inga plant in Zaire is a case in point.

Moreover, over the past decade, the cost of generating plants has risen proportionally more sharply than the cost of transmission facilities.

Coupled with the huge increase in oil prices, this has made it economically convenient to install electricity transmission facilities covering the longest technically viable distances.

Furthermore, transmission costs could be sharply reduced by implementing projects that do not simply copy similar schemes in the industrial countries, but projects which are specially tailored to the needs of the developing countries themselves.

Due account therefore has to be taken of the following facts:

— Radial supply is often acceptable using a simple-circuit transmission line.

— In some countries (many African countries, for example), ice does not form on the conductors, and in many of them the wind speed is often less than 100 km/hour.

— Only minor damage is generally done by failures in view of the low level of industrialization and the social state of communities that are less accustomed to an almost total continuity of supplies.

— The load in the regions concerned is mostly residential-agricultural-commercial, and any variation in the active and reactive load is therefore slow, while the power factor is comparatively high. Under such conditions, more economical, and both simple and reliable, facilities can be used to adapt the degree of shunt compensation of the lines to match the load variations and regulate the tension.

With regard to the HV overhead lines, which account for the bulk of the cost of these transmission facilities, the favourable climatic and territorial conditions make it possible to envisage reduced mechanical load and special types of supports and foundations meeting local conditions.

Measures of this kind leave a considerable margin for cutting the cost of electricity transmission to a level which can offer the user energy at far more attractive prices than local diesel-fired electricity, even over hundreds of kilometers and via lines bearing only a fraction of their surge impedance loading.

On the subject of the guarantees required for the international transmission of large quantities of electric power, any possible weakness in the political guarantees should be reinforced by constraints making it economically worthwhile, without giving up local reserves for essential needs.

Utilization of the hydroelectric potential of Third World countries and the parallel construction of energy-intensive plants.

According to the latest information, as I said before, a great deal of the world's untapped hydro energy resources are concentrated in Africa, Asia and Latin America. Table 6 provides a few examples of some great hydroelectric systems now in the construction or planning stage or under study.

Any cost evaluation, however, would be much more unreliable, once again because of the fluctuation in the purchasing power of currencies,

TABLE 6 - *Some major hydroelectric developments under study, planning and construction.*

Country	RIVER (Principal Hydroelectric Developments)	Capacity MW
AFRICA		
Zaire	ZAIRE (Inga III)	3,520
	ZAIRE (Grande Inga, Pioka, Matadi)	68,400
Mozambique	ZAMBESI (additional potential sites)	5,030
South Africa	TUGELA (Kotongweni, Ntulwana, Nvumose)	3,700
AMERICA		
Canada	LA GRANDE (La Grande phase 2, La Grande Baleine, Nottaway-Broadback-Rupert)	13,600
	NELSON (additional potential sites)	5,600
	COLOMBIA (Revelstoke)	2,700
Mexico	GRIJALVA (Chicoasen)	2,400-5,000
Brazil	TOCANTINS (Tucuruì, additional potential sites)	7,260
	SAO FRANCISCO (Itaparica, Paulo Alfonso IV, Xingo)	6,700
Brazil Paraguay Argentina	PARANA and tributaries (Itaipu, Corpus, Yaciréta Apipe)	22,000
Brazil Argentina	URUGUAY (Roncador, Garabi, Sao Pedro)	5,800
Venezuela	CARONI (Guri project)	10,500
ASIA		
U.S.S.R.	YENISEI	23,500
	ANGARA	12,000
China	YAUGTZE (Gorge Dam Hydro Project)	25,000-30,000
	YAUGTZE (Gezhouba Project)	2,700

which introduces a factor of great uncertainty when it comes to estimating the cost of installation, whether they are scheduled for construction or merely under consideration.

On the basis of hydroelectric projects now under way and of other available information, it can be said that, among the hydraulic resources of those continents, there are some which could certainly produce the cheapest power available anywhere in the world.

The attainment of the proposed goals demands a total system approach bearing not only on power generation but also on its utilization in the vicinity of power plants and its transmission over long distances to supply consumption centres developing at a rather fast rate.

It is evident that the nature, size and scope of the problems posed by the attainment of the proposed goals call for international cooperation.

Four important categories of problems in this area are:

— technological and planning problems;

— commercial problems, and

— financial problems, to which

— political problems are inevitably added.

The technological problems involved in designing and building hydroelectric installations are undoubtedly very substantial, given the size of the projects, the considerable capacity of the plants, the great transmission capacity and the length of the interconnecting links. Towards the solution of these problems, local capabilities and skills require an efficient integration, which can be provided by power generating and distributing utilities, as well as by the engineering and construction contractors existing in the countries possessing old traditions in the hydroelectric area. We can say, in this respect, that the capabilities available on a worldwide scale are amply sufficient. International cooperation through joint ventures would of course be desirable for certain major projects, towards combining the efforts of two or more countries.

It should be mentioned at this point that Italy is one of the countries possessing the greatest experience and entrepreneurial capabilities in this field, as proved by its substantial contribution to the construction of some of the largest plants shown in Table 6.

These considerations, of course, also apply to the planning of the utilization of hydraulic resources with a view to meeting other requirements than power generation: flood control, inland navigation, irrigation, etc.

Commercial problems are certainly far from negligible and in all cases they prove very delicate and complex.

In effect, a speeding up of construction plans requires a parallel acceleration of the implementation of programs for power utilization as it becomes available.

This will involve, insofar as possible, local utilization as well as utilization at varying distances from production centers; the option, of course, will depend upon the specific circumstances.

As it is impossible to make here a more detailed study of this or that particular situation, it will be wise to stick to general considerations. In this order of ideas, it will be useful to focus the attention on the nature of the feasible commercial production, taking into account the following points:

a) specific electric power consumption, or amount of power consumed per unit of product weight;

b) present product consumption and future-demand forecasts;

c) capital investment required per unit of product per year ("specific investment" or "capital cost");

d) present product price per unit of weight;

e) labour required per unit of product.

All of the above applies, of course, to large-size factories.

Table 7 shows the 1980 world production of energy-intensive products, broken down by large geo-economic areas. The table evidences that said production is concentrated in industrialized countries, especially in the market-economy ones. For a few of these countries, mainly in the European area, Fig. 1 gives the incidence of the energy-intensive industries consumption over the overall power consumptions and industry consumptions in 1980. In the countries taken into consideration the aforesaid products absorbed more than half (almost three quarters in the case of Belgium) of the electricity industrial consumption, and a share ranging from 35% to 57% of the overall national consumption.

Let us now move on to some general considerations, apart from the points covered thus far.

In the making of choices, the productions that seem to deserve priority are those characterized by the following factors:

a) a world demand increasing at such a rate as to easily absorb the

TABLE 7 - *1980 output of materials with high energy content.*

Materials	Industrialized Countries				Third World		World Total
	Market Economy		Centrally Planned				
	Million t	%	Million t	%	Million t	%	Million t
Crude steel	393.9	56	208.6	29	103.9	15	706.4
Pig Iron and Ferro Alloys	283.3	54	145.4	28	97.1	18	525.8
Aluminium (Primary and Secondary)	14.4	77	2.3	12	2.0	11	18.7
Zinc (Primary Only)	4.3	78	1.1	20	0.1	2	5.5
Magnesium	0.3	78	0.1	20	—	2	0.4
Caustic Soda	21.1	67	5.2	17	5.2	16	31.5
Wood Pulp - Mechanical Pulp	22.6	85	2.4	9	1.7	6	26.7
Wood Pulp - Chemical Pulp	79.5	83	8.6	9	7.4	8	95.5
Newsprint	21.9	83	1.7	7	2.6	10	26.2
Other Paper and Paperboard	115.9	78	12.3	8	19.8	14	148.0
Cement	392.6	45	187.5	22	287.6	33	867.7

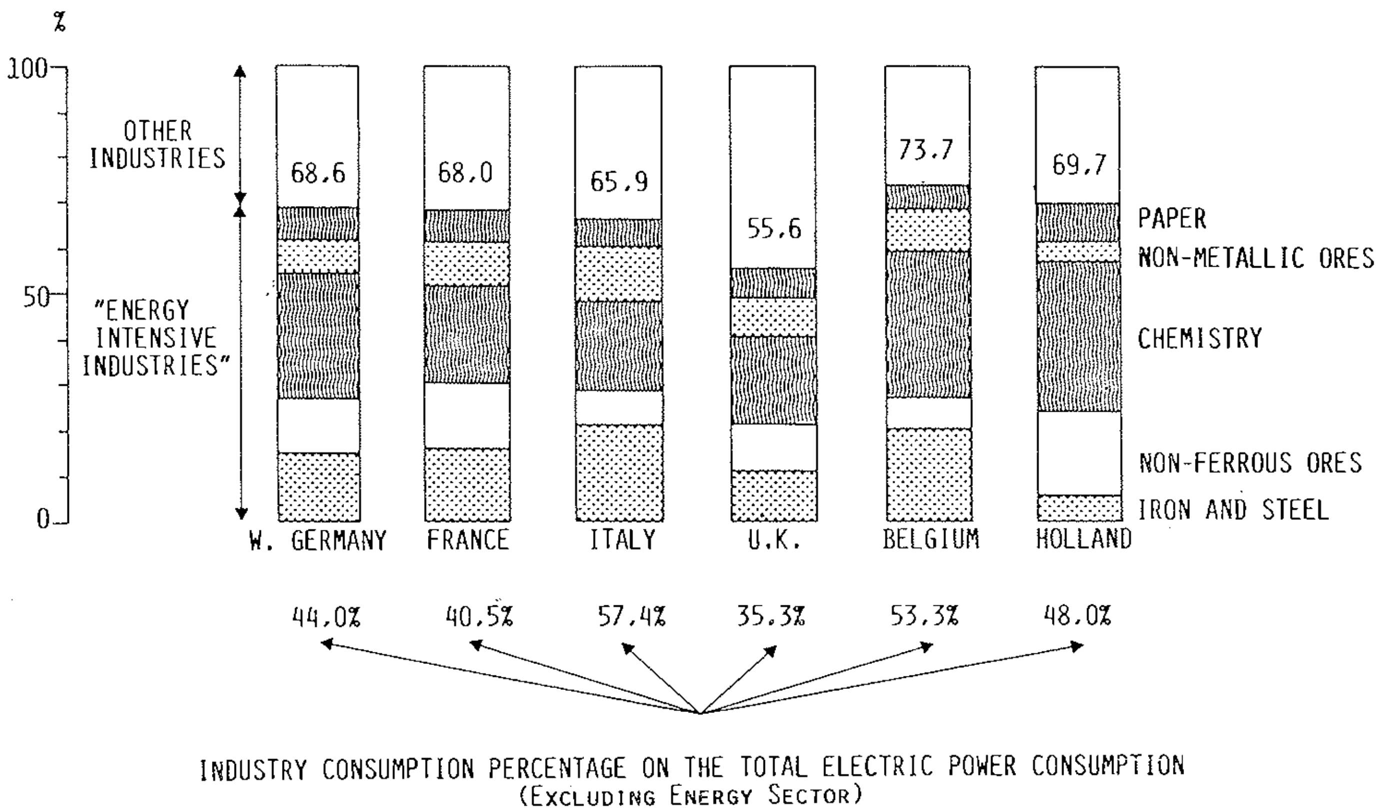


FIG. 1. Contribution of energy-intensive industries to electric power consumption for industrial uses (1980).

Source: Eurostat - Bulletin Mensuel d'Energie Electrique - 12/1981.

new production and to warrant, if need be, giving up the construction of any other production units for a certain number of years;

b) high specific power consumption. This involves transmitting substantial quantities of energy in latent form in certain productions (enriched uranium, aluminium, etc.) over long distances;

c) high worth of the product per unit of weight, to limit the hurden of the transportation cost on the final cost of the product;

d) a "capital cost" as low as possible, in order to reduce the financial effort;

e) a relatively low labour intensity, in order to facilitate the solution of social problems in the frequent cases of installation sited away from population centers.

The financing problems of the enterprises engaging in the ventures discussed here are considerably great and also involve certain risks for which allowance should be made. Nor can we overlook their political aspect, which necessarily requires choices and guarantees on the part of the governments of the nations interested in utilizing the available resources. Such questions do not lie within the purview of this discussion, and therefore we must confine ourselves to remarks of a great nature.

The attainment of the goals listed above depends quite evidently on the meeting of the intents and interest of the two partners, and namely:

— the countries possessing hydraulic resources that would for a long time remain unutilized in the absence of agreements with other countries;

— a foreign contractor or an international consortium possessing technical and organization capabilities as well as financial resources or credit in rather large amounts, sufficient to initiate and successfully complete in cooperation with the country concerned, a program for the harnessing of the available resources and even for their utilization, at least for a certain number of years.

The intent of the partners depends upon political evaluations and on their respective interests. Without discussing in particular such evaluation, we stress that as regards their interests a distinction should be drawn between a general aspect and a particular one.

We feel that the general aspect was pointed out adequately in the preceding discussion.

The particular interest of the country possessing unused hydraulic resources lies in the possibility of speeding up by several years its industrial development, and thus accelerating the improvement of the standards of living of its people.

The domestic utilization of large amounts of power could initially create advantages for mass productions, but later also for increasingly specialised productions, providing further benefits to the economic welfare of the country.

Whatever the nature of the agreements with the country or countries cooperating on the construction and operation of the plants, benefits will certainly accrue to the country concerned, from the viewpoint of its foreign balance of payments.

The financing of projects is a complex problem, given their size and the monetary situation. Without going into details, we shall confine ourselves to considering a solution based on a partial or total repayment of the capital borrowed for investment in the construction of hydroelectric installations, through the supplying, over a certain number of years, of a relatively major portion of the power generated to industries located in the country, as close as possible to the power plants. This supply will be handled by industrial concerns directly or indirectly connected with the financing operations. The problem is undoubtedly complex and several solutions should be considered, in the light of the particular prevailing conditions. The one we have considered involves a repayment "in kind" of the funds borrowed to finance the investment projects.

The contractors or consortia engaging in the implementation of the large-scale programs for the utilization of available hydraulic resources should also find their own interest in the cooperative arrangements.

The problem is simple when this cooperation involves only limited financing, but this case is likely to prove rather infrequent. When large financing is needed, the operation becomes more complex and calls for different solutions to suit the various cases.

In the case of the solution outlined above, the foreign contractors may be interested in sharing the benefits deriving from a supply of cheap power with a satisfactory degree of reliability.

We cannot dwell here on a subject which falls outside the scope of this discussion: all we can do is to mention a very important and delicate problem with certain political implications.

This problem concerns the risks inherent in any venture involving long-term financing of projects requiring substantial investments.

What is involved here is not technological contingencies, but rather consequences of political events or upheavals which might alter the balance of economic or industrial relations between partners.

Hence, the need for a system of guarantees designed to make the governments assume responsibility under international arrangements.

There is no need to dwell any further on this problem, which is of concern to the specialized international bodies.

It is to be hoped, in any event, that the arrangements designed to ensure international cooperation and multilateral guarantees will soon yield concrete results.

DISCUSSION

CHOUCRI

My comments are directed to Mr. Lemkecher's very interesting and provocative paper, which has given us a view of alternative mechanisms for attracting investments in the exploration and development of the oil and also of natural gas sectors. My question pertains to the first of the six criteria he has given us: the availability and channelling of local funds. It is our impression that local funds exist in many countries of North Africa. What is not in place are the incentive mechanisms, the tax structure, the additional sustaining financial arrangements which can mobilize local capital. What can be envisaged to mobilize availability of local capital?

Let me take up natural gas. Natural gas development in Tunisia, Mr. Lemkecher told us, is directed to domestic use only. So the pricing of natural gas products need not necessarily follow international gas product prices. My question has to do with the logic and rational underlining of the eventual pricing structure for natural gas. What would be the correct pricing structure?

On the basis of your comment I have assumed there is no provision for gas clauses in oil contracts. Where there is a possibility of writing gas clauses into the oil contracts, many of the difficulties might somehow be alleviated.

Finally a brief comment on Prof. Angelini's paper. He commented on the prospects of the necessity of international cooperation, primarily between the industrial societies and the developing countries. On a theme which was raised this morning by Miss Carter, may I suggest that we turn our observations in the days to come onto the prospects of cooperation, collaboration, exchange of information, exchange of institutional know-how and arrangements among developing countries themselves? We have not really spent any time talking about South-South relations. There is much to be said for at least exploring viable mechanisms of enhancing collaboration between developing countries in the oil sector.

DESPRAIRIES

Mr. Lemkecher, you presented a very concrete case, one that is a little out of the average, because you described a very small structure. I shall try to answer your remarks. In the case you presented, the structure is very small, but it should be exploited, if you have a favourable tax system, which will allow you to find rentability in exploitation. Amortization would allow the company not to pay any taxes on the production for a very long time, and the depletion allowance means that there will virtually never be any taxes to pay. The government has to make a choice. Either it gets the money but no oil, or it gets the oil and no tax money. The ideal solution must be a sort of compromise between the two extremes.

ZEGHBIB

Je rejoins Monsieur Despraíries sur le cas, disons limite, qui a été présenté. Je crois qu'une philosophie différente doit être adoptée quand il s'agit de l'exploitation des petits gisements, surtout des pays en voie de développement. Il s'agit de faire un choix de politiques économiques et stratégiques tout court. On ne peut pas adopter une simple logique du profit. Parmi les actions nommées par Monsieur Lemkecher, l'action sur les prix des produits dérivés du pétrole, j'ai une remarque à faire. Je crois qu'il faut voir la structure du baril, trouver le produit sur lequel agir, et évaleur les effets qu'on induit sur l'ensemble des activités économiques.

Reprenons maintenant les points soulevés par Miss Choucri sur la collaboration Sud-Sud. Vous avez dit qu'il y a une compagnie d'un pays en voie de développement qui est en train de faire des prospections. J'aimerais savoir si le contrat avec cette compagnie est différent des contrats que vous signez avec les compagnies multinationales.

CARTER

Both Mr. Matsui and Mr. Angelini made the point that with cheap renewable energy the developing world would or could become a magnet for the energy intensive industries or the industrialized world. Now, there might well be a natural development but one would hope, and one would sound a word of caution that these developments be pursued with care. In some cases, the transfer of second-hand plants has caused pollution problems, and the most advanced technologies have not been transferred.

KONAN

Monsieur Lemkecher, je crois qu'il est dangereux d'indexer le prix du gaz sur le prix du fuel, spécialement quand l'un est un produit national et l'autre est importé. En parlant du déficit énergétique, il y a une interconnection électrique entre votre pays et les autres pays d'Afrique. Est-ce qu'elle donne de bons résultats?

LEMKECHER

En répondant à Miss Choucri sur les questions qui m'ont été posées sur les moyens envisagés pour drainer des ressources financières privées pour les investissements pétroliers, laissez-moi dire que la Tunisie est un petit pays où l'épargne privée, petite et moyenne, est axée sur l'agriculture et l'industrie, et donc clairement pas intéressée au développement des gisements de pétrole.

En ce qui concerne les clauses dans les conventions sur la découverte de gaz, pendant les dernières cinq années on n'a introduit que de petites clauses très limitées. On est en train de mettre au point un code pour le développement du gaz et des gisements marginaux.

Le prix du gaz sera axé sur le prix international du fuel lourd. Ce n'est qu'une base, on n'a pas la formule finale; nous sommes en train d'élaborer une tarification.

A titre d'information, le cas que je vous ai présenté n'est pas désespéré. En faite, il a donné lieu à un développement. Les sociétés pétrolières sont traitées toutes de la même façon.

L'interconnection électrique marche très bien, et on est en train de la faire avancer. C'est une pierre, qui reste en place.

SMITH

A comment for Prof. Angelini. I hope that the environmental impacts related to hydropower development, as well as its social impacts will be taken into due account.

ANGELINI

Yes. I have not touched on the point that you are making because the lack of time would have made my report too long. Environmental problems are being studied with care.

SOME GENERAL REMARKS

BJÖRN BARTH
Director, Office of Oil Market Developments, International Energy Agency
2, Rue André Pascal, F-75775 Cedex 16, Paris, France

I am very pleased to be able to speak in this forum on Energy and Developing Countries. The International Energy Agency, where I work, is not a development agency. It is frankly concerned mainly with the energy and energy policy interests of its member countries which include most western, industrialised countries. However, it is clear to me and to IEA member countries that there is an overall common interest between developing and industrialised countries. Thus it may be possible to identify areas for potential cooperation. I am referring, of course, to our common interest in an energy secure future — a future in which energy crises do not inhibit economic progress in either developed or developing countries.

Today I am going to talk about a potential conflict between energy security and economic development in the decades ahead. In rough terms, economic progress leads to increased energy consumption, eventually reversing the current excess supply situation in world energy markets. The result is a tighter oil market which is vulnerable to an oil price shock, like those of the 1970s, which would present special difficulties for oil-importing developing countries, but which also would prevent industrialised countries from realising their economic objectives. Oil producing countries too have an interest in averting future price shocks. As events of the last few years have clearly illustrated, a sharp oil price increase leads, within a few months or years, to declines in oil demand and economic growth together with increases in interest rates and inflation. These things are all harmful to oil producers as well as consumers.

I am also going to talk about the kinds of efforts which must be made in order to prevent economic development aspirations from colliding with energy market limitations. Such a collision must be avoided because it would have potentially grave consequences.

Allow me to begin by discussing the relationship between economic progress and energy consumption — more accurately, the relationship between measured economic growth and energy consumption. Prior to 1973, among the OECD group of industrialised economies a 1 percent increase in economic activity (as measured by Gross Domestic Product or GDP) was associated with a 1 percent increase in energy consumption. Of course, energy prices were stable during this period. Since 1973, and especially since 1979, sharply higher energy prices have made it worthwhile to conserve energy and OECD economic activity has been able to increase more rapidly than energy consumption, and much more rapidly than oil consumption.

Figure 1 illustrates quite clearly the historical relationship between energy consumption and economic growth in industrialised countries.

— Total energy consumption and oil consumption both grew parallel with economic activity during the 1960-1973 period — when energy prices were very stable.

— After the 1973 oil price shock, energy consumption and especially oil consumption increased more slowly than in the earlier period. Consumption increased more slowly in absolute terms, and also in relation to economic activity.

— Finally, the 1979-80 oil price shock precipitated a major adjustment process in OECD countries. The linkage between increased energy consumption and economic growth has been temporarily broken while OECD economies adjust to higher energy prices.

It is worth considering what is meant by energy conservation. Energy conservation can derive from something so simple as driving more slowly or turning down the heat in buildings. In such cases, energy consumption might quickly rebound if the price of energy were to fall. More lasting, basically irreversible energy conservation derives from the replacement of old, inefficient energy-using equipment by more modern equipment which is designed with expensive energy in mind — energy-efficient machinery, buildings and so on. This process can continue until the entire capital stock is eventually modernised. Dramatic changes in energy prices tend to speed up this replacement of obsolescent capital goods. So does rapid economic growth. However, eventually this process will be largely completed and when it is, I would argue that a rough one-to-one relationship between increases in energy use and economic growth such as prevailed in the 1960s, will be re-established. It may be many years before the

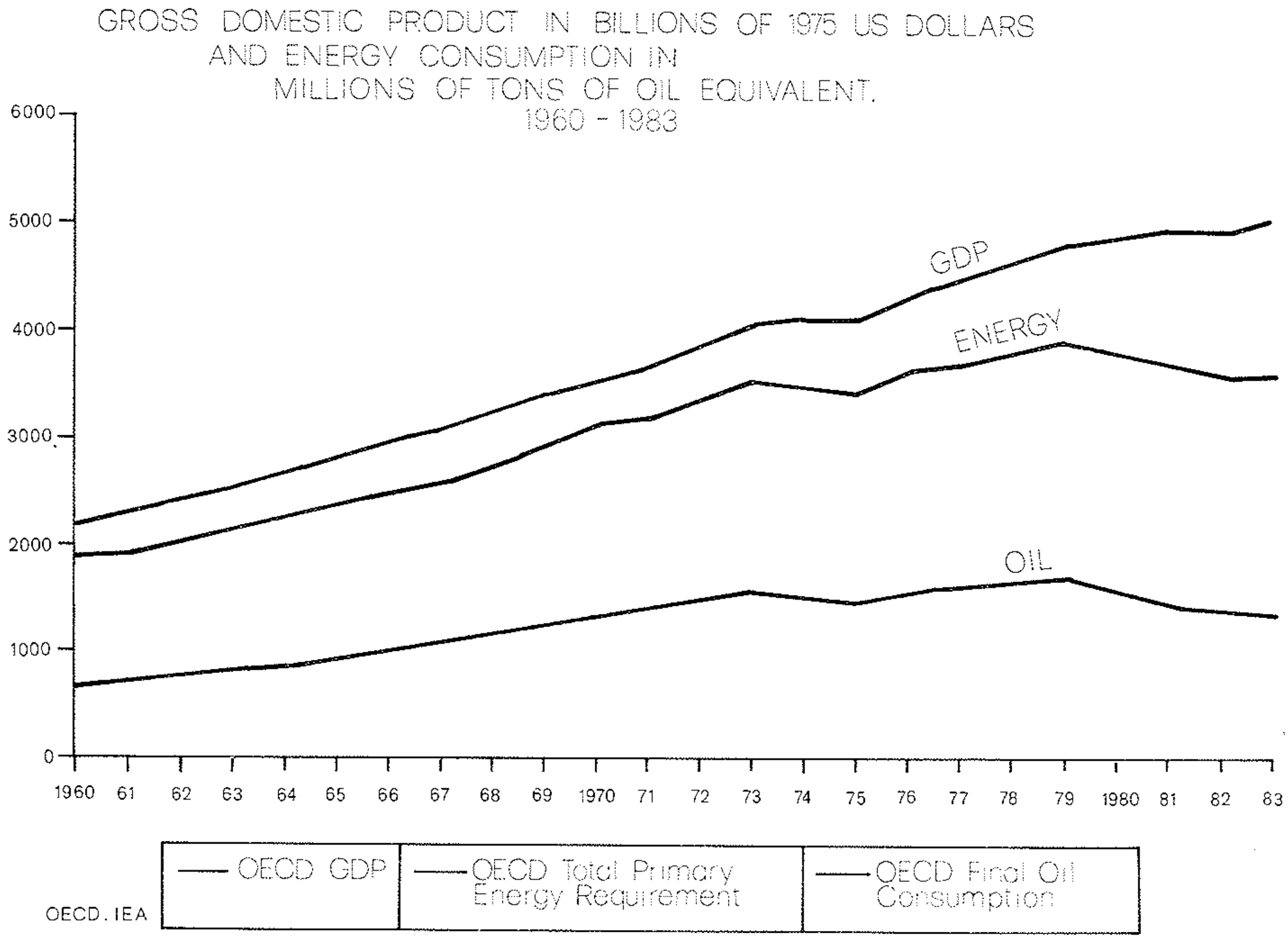

GROSS DOMESTIC PRODUCT IN BILLIONS OF 1975 US DOLLARS
AND ENERGY CONSUMPTION IN
MILLIONS OF TONS OF OIL EQUIVALENT.
1960 - 1983
6000
5000
4000
3000
2000
1000
0
GDP
ENERGY
OIL
1960
61
62
63
64
65
66
67
68
69
1970
71
72
73
74
75
76
77
78
79
1980
81
82
83
OECD GDP
OECD Total Primary Energy Requirement
OECD Final Oil Consumption
OECD. IEA

Fig. 1

capital stock is fully geared to today's expensive energy, but barring further energy price shocks the process will eventually slow down as it nears completion.

Similar relationships hold true for developing countries. There is a strong positive association between energy consumption and measured economic growth, altbough this relationship may be blurred by energy conservation measures while the economy adjusts to a new set of energy prices.

The relationship between energy use and economic growth operates in both directions. In some senses increased energy use is merely a by-product of increased economic activity. In other ways, increased energy use is an essential ingredient of economic progress. I would like to dwell on this point for a moment. Economic growth can be conveniently thought of as the sum of two components — population growth and increased output per person, or productivity growth.

Energy demand responds quite passively to population growth. More people need more fuel to cook with, more transportation services, and so on. The alternative is declining physical comfort. The relationship between population growth and energy demand is not rigid, especially as economies adjust to large increases in energy prices, but in general population and energy consumption grow apace.

On the other hand, energy is a key, active ingredient of economic progress. Replacing or augmenting human muscle energy is a central factor in increasing output per person in many developing countries. Increasing the per-capita use of non-human energy may be almost essential to increasing the material well-being of men and women in developing countries. In this very real sense, energy fuels economic development. For this reason, it is essential that adequate energy supplies are available in the future so that the economic aspirations of developing countries are not thwarted by energy crises.

Table 1 illustrates the historical relationships between energy use, population, and economic activity for several developing countries. The countries and the time period were selected simply because the data were readily available. They do not constitute a representative sampling of developing countries.

— The relationship between energy consumption and population growth is most vividly illustrated by the more narrow relationship between non-commercial energy use growth and population growth. Non-commercial energy sources mainly supply domestic, household energy needs

TABLE 1 - *Average Annual Growth in Population, Gross Domestic Product and Energy Consumption for Selected Developing Countries, 1983-1984.*

	Brazil	India	Malaysia	Tunisia	Zimbabwe
			(per cent)		
Average Annual Increase					
Population	2.7	2.0	3.1	2.5	3.2
Non-Commercial Energy Consumption	2.7	2.7	2.6	2.3	2.8
Average Annual Per Capita Increase					
Gross Domestic Product	3.0	2.1	4.2	4.9	−0.6
Commercial Energy Consumption	2.6	2.1	3.4	6.7	−2.2
Oil Consumption	1.1	2.7	2.9	6.1	−2.7

Source: IEA, IMF

for cooking and heat. Notice the similar growth rates for population and non-commercial energy use in each country. More households simply require more energy, although there is always room for increased efficiency to alter this relationship.

— The lower panel displays per capita increases in commercial energy use and oil use along with per capita economic growth. Although the relationship is not rigid, higher rates of growth in per capita energy use are associated with higher rates of increase in per capita economic activity. In this sense, energy consumption fuels economic growth.

One wonders, with today's weak oil market in which potential supply greatly exceeds demand, is it necessary to even consider the possibility of further energy crises in the decades ahead? I helieve that the only prudent answer is yes, and we need to work actively to ensure future energy availahility.

Let me explain why I think this is so. This analysis will be concerned exclusively with oil. Of course other fuels are important, but for the rest of this century oil is the fuel which poses the threat of shortages and price shocks which could disrupt world economic progress.

Today the world's capacity to produce oil exceeds its current consumption by perhaps as much as 10 million barrels per day. World oil demand especially in industrialised countries is very depressed in response to the oil price shocks of the1970s and the economic recession of the early 1980s. However, it is very possible that world oil demand could expand to take up all the slack in world oil markets within a decade or perhaps a bit more.

To begin with, we all hope that recession and oil price shocks are behind us. With renewed economic growth in industrialized countries, we can expect some increase in energy demand. The ongoing adoption of the capital stock in the industrialized countries of the Organization for Economic Cooperation and Development, the OECD, means that energy demand will grow more slowly than overall economic activity. Oil consumption should grow even more slowly than total energy consumption because natural gas, coal or nuclear energy sources should continue to replace more expensive oil. However, it seems imprudent to simply assume that oil use in industrialized countries will continue to decline as it has in recent years. Given sustained economic growth, it seems reasonable to assume that OECD oil demand will stabilise at roughly 35-36 million barrels per day late in this decade after rebounding slightly from the 1983 recession level of approximately 34 million barrels per day. This 34 million barrels per day constituted roughly seventy-five percent of total oil consumption last year, in the world outside centrally planned economies. Thus for three-quarters of the current oil market, demand will grow only slowly because:

1) the economies are already more or less fully industrialized;

2) the as-yet-unexploited opportunities for conservation are large for the time being; and

3) the availability of alternative fuels allows some substitution away from oil.

The developing world used roughly one-quarter of world oil consumption, about 10.5 million barrels of oil a day, last year. This share should grow rapidly as population growth and economic development combine to increase fuel consumption. Energy consumption might roughly double by 2000 in developing countries. There is a great deal of uncertainty about the scope for conservation and interfuel substitution in developing countries. Also, high operating costs for oil-fired equipment must be weighed against high capital and infrastructure costs for non-oil fuels in investment decisions. It seems prudent to assume that oil consumption will roughly maintain its current share of developing countries' energy consumption. This implies an increase in oil consumption of 7-12 million barrels per day.

On the supply side of the ledger, OECD supply is expected to decline by two or three million barrels per day while non-OPEC developing countries' production may increase by 2-4 million barrels per day. This means that OECD and non-OPEC developing countries together will need 28-30 million barrels per day of imported oil by 2000 compared to roughly 20 millions barrels per day in 1983. The current excess production capacity, which may be as great as 10 million barrels per day, will be gradually eliminated.

Table 2 provides an illustrative adding up of world oil supply and demand based on the kind of scenario which was just discussed.

— This is not a forecast. Rather, it is an illustrative scenario which might be described as very "middle-of-the-road". Nonetheless, it leads to a requirement for OPEC production of crude oil and natural gas liquids of 29 million barrels per day in 2000 compared to 18.5 million barrels per day in 1983.

— A scenario somewhat more optimistic on both supply and demand could lead to a requirement for OPEC oil of perhaps 25 million barrels per day in the year 2000. Although less alarming, this still represents a serious tightening of world oil markets from today's excess supply situation.

— An equally reasonable, but slightly less optimistic scenario would bring the requirement for OPEC oil to 30 million barrels as soon as 1995.

I wish to emphasize that this is not a deliberately alarmist scenario. It is based on reasonable, achievable assumptions regarding oil production. It has almost no growth in OECD countries' oil consumption. It has developing country oil consumption growing only at about 3.7 percent per year which would not be sufficient to support historical rates of economic growth. One would hope that higher, even much higher rates of economic growth could be sustained by developing countries. However, higher rates of development will be associated with greater energy use and will lead to tighter oil markets than would otherwise obtain.

Tighter oil markets may lead to a gradual increase in oil prices — the one or two percent real annual oil price increases which are built into so many economic forecasts. This would create difficulties for oil consumers but the situation could be managed. More alarming is the risk that tighter oil markets and the associated increasing reliance on imported oil from the Middle East may lay the groundwork for another oil price shock. I don't wish to suggest that any country would deliberately cause such a shock, since the interests of producers and consumers alike are harmed

TABLE 2 - *Illustrative World Oil Demand and Supply Assumptions, 1983-2000.*

	1983	1990	1995	2000	Average Annual Growth Rate 1984-2000
	(million barrels per day)				(per cent)
DEMAND					
OECD	33.9	34.6	35.1	35.7	0.3
OPEC	3.0	4.2	5.4	6.9	5.0
Other Developing Countries	7.6	9.3	10.8	12.6	3.0
TOTAL	44.5	48.1	51.3	55.2	1.3
OECD and NON-OPEC DEVELOPING COUNTRY PRODUCTION					
OECD	15.9	14.8	13.7	13.0	
Mexico	2.8	3.5	3.7	4.0	
Other Non-OPEC Developing Countries	4.5	6.0	6.5	7.0	
Processing Gains	1.0	1.0	1.0	1.0	
TOTAL	24.2	25.3	24.9	25.0	
IMPORT REQUIREMENTS OF OECD and NON-OPEC DEVELOPING COUNTRIES BY SOURCE					
Centrally Planned Economies	1.6	1.3	1.0	1.0	
OPEC	18.5	21.5	25.4	29.2	
TOTAL	20.1	22.8	26.4	30.2	

Source: IEA

by such events. Instead, tight oil markets mean that relatively minor supply disturbances caused by political or even climatic events can quickly translate into very large price increases.

Let us look now at the pattern of oil supply, by source, from 1960 to 1983 with projections to the year 2000. The projected values are based on the "middle-of-the-road" scenario described earlier. For convenience, the distinction between OPEC and non-OPEC production is based on OPEC's current membership.

— Despite increasing non-OPEC production during the 1960s, reliance on OPEC oil and especially Middle-East OPEC oil increased dramatically.

— In 1960 most oil production took place outside the OPEC group of countries.

— By 1965 OPEC production exceeded non-OPEC production.

— And by 1970, Middle-East OPEC production exceeded non-OPEC production. The Middle-East was producing at very high levels of output during the 1970s, both absolutely and in relation to other regions.

— Because of this large reliance on Middle-East oil during the 1970s the world was very vulnerable to interruption in the oil supply from this region. Political events, not a desire on anyone's part to manipulate oil prices, led to oil supply interruptions, which quickly translated into large price increases.

— Projected production levels indicate that the world may once again become very dependent on imported oil from Middle-East OPEC countries during the 1990s.

— Even in the "middle-of-the-road" scenario depicted here OPEC will account for more than half of world oil production by the middle of the 1990s.

— By the end of the 1990s, Middle-East OPEC production may again be approaching the very high levels of the 1970s.

We face an apparent dilemma. Rapid development, which we very much desire, may tighten world oil markets and thereby make us vulnerable to an oil crisis which would bear especially heavily on oil-importing developing countries.

It is clear that the answer to this dilemma must not lie in limiting the growth prospects of developing countries in order to save oil. It is also clear that we must not allow future oil price shocks to stifle the aspirations of the developing world in the decades to come.

Instead, we should concentrate our efforts to ensure that adequate hydrocarbon supplies are available to support the economic growth of developing countries without setting the stage for another oil crisis. This requires sustained efforts on three fronts.

First, there must be continued efforts toward more rational energy use in both developed and developing countries. The current slack in world oil markets must not be allowed to create a sense of complacency. Industrialized countries must continue the long-term job of restructuring domestic energy use away from oil, especially imported oil. This means that fiscal and financial incentives to energy conservation and interfuel substitution must be continued, and perhaps even enhanced. Oil products must be priced so as to reflect the actual cost of oil in world markets and to encourage the substitution of other fuels for oil. Industrialized countries should continue to phase out oil-fired electrical generation. In general, all countries need to ensure that investments in long-lasting energy-using equipment reflect the longer term reality of tighter oil markets.

The potential gain from these efforts is very large. For example, in the OECD countries oil's share of total energy use declined from 50 to 45 percent, and at the same time total energy use relative to economic activity declined substantially during the last 10 years. The industrialized countries must make every effort to sustain this conservation and fuel switching momentum despite recent oil price declines, and developed countries must ensure that they use energy as efficiently as is economically justified.

Second, industrialized countries must make major efforts to deal quickly with the issues surrounding development of non-oil energy production and use. There are difficult, contentious political and environmental issues inhibiting the relatively abundant coal and nuclear energy resources of industrialized countries from displacing scarcer oil — issues such as acid rain, nuclear safeguards and nuclear waste disposal.

Equally important political and economic challenges for industrialized countries surround increasing use of imported natural gas in Europe, the exploitation of North America's oil sand and oil shale resources, and the development and transportation of Arctic natural gas.

Given the long lead times required to exploit any of these resources, it is important that these issues be promptly resolved so that appropriate investments are made — and inappropriate investments forestalled.

Finally, major cooperative efforts must be made to identify, develop and employ the indigenous energy resources of developing countries. In the past, the energy resources of many, perhaps most developing countries have not been adequately assessed. Although there is evidence of increasing efforts to explore for and develop the hydrocarbon resources of developing countries in the last few years, much greater commitment is required. Energy supply projects in developing countries, like their counterparts in developed countries, often pose very difficult environmental, political and economic challenges.

One difficulty, of course, is that such efforts are very costly, very risky and very technically demanding. The demands on technical and financial resources are too great for many developing countries and international development institutions. For those developing countries which are willing to accept the presence of multinational, private oil companies, these can offer a source of funds and expertise. There are costs associated with this approach. If oil is discovered, some of the value of that oil will leave the country as profits of the foreign investor — the oil company would characterize this as returns on its investment.

An alternative is for developing countries to simply hire the services of the multinational oil companies to drill wells and install production equipment. This approach has its obvious benefits to the host country, but also it has its risks. In particular, the costs of exploration must be paid whether or not oil is discovered. This approach is therefore most appropriate where the geological prospects are very good.

International organisations can help developing countries to assess their geological possibilities so that: 1) foreign investors can be attracted and 2) countries can negotiate the type of agreement (risk or service) appropriate to their circumstances and at the most advantageous terms consistent with their geological prospects.

If international capital and expertise are to be further mobilised for a major effort to find and employ the hydrocarbon resources of developing countries, then an atmosphere of mutual trust and respect must be created. There is a wide array of issues to be discussed. Officials, men and women, from developing countries, banks, oil companies, and international organisations need to exchange their points of view. Each group needs to appreciate the limitations which circumstances place on all the other groups. Then, we can hope that more economic resources will be committed to the search for oil and gas in developing countries under terms which can endure because they are regarded by all parties as a realistic balancing of interests.

To summarize, huge efforts are needed:

— by developed countries to conserve energy, especially oil and by developing countries to use energy efficiently;

— by developed countries to exploit their non-oil resources in environmentally and politically acceptable ways so as to minimize oil consumption; and

— by developing countries to find and employ their indigenous hydrocarbon and other energy resources.

If these efforts are successfully made, then energy will be fuel for economic development rather than an obstacle to economic progress.

THE OPPORTUNITY OF MULTI-PURPOSE NUCLEAR REACTORS FOR DEVELOPING COUNTRIES, WITH PARTICULAR REGARD TO DESALINATED WATER PRODUCTION

MAURIZIO CUMO
University of Rome "La Sapienza"

At present, nuclear energy has already shown its convenience in comparison with the fossil resources. This convenience will certainly increase in the coming years. Nowadays, the size of nuclear power plants spans from 1,000 to 1,300 electric megawatts. Next target is about 1500 Mwe.

These sizes are requested for electricity production with integrated electric networks for the transmission of an electric power, at least ten times greater; that is to say that such reactors — mainly with pressurized light water — serve only for the requirements of medium sized or of large countries, well advanced in technological development.

Their employ is more difficult in the developing countries, because of the lack of great electric networks. For such countries the size of 200-400 MWe is much more suitable, even if it is obvious that, reducing the size, the cost of electricity increases.

The cost of the kilowatt-hour produced by nuclear plants is lower than the corresponding costs from fossil plants. So, even reducing the plant size, the convenience holds true. But the economic convenience increases abruptly in a multi-purpose reactor, with a combined production of electricity and heat. Heat for industrial and civil uses and for water desalination. In this case the slight reduction in the electricity output is largely counterbalanced by the production of heat, with a great economic margin in comparison with the fossil resources.

The design of a convenient multi-purpose reactor of 200-400 MWe requires a set of conditions, as, for instance, its use in a developing country with reduced electric networks and technological facilities.

First of all, it is necessary to standardize the design for a series of many units in order to achieve all the scale advantages. Moreover the safety requirements have to be maximized, with characteristics of intrinsic safety. Fission products release has to be forbidden by passive systems, even when the control of the plant is lost for a long time. The fuel should be of the most diffused commercial type, but employed at a very low rate, so as to increase the refuelling period up to a couple of years, during short periods of maintenance by external technicians.

Nowadays nuclear engineering is perfectly able to produce such a reactor, which seems to have interesting features particularly for Arab countries. What is necessary, however, is to define previously the range of plant characteristics (electricity and heat outputs) in order to meet the needs of many countries, so as to reach a consistent number of units with a valid, standardized design, which only a great concentration of electromechanical factories can warrant.

In the organisation of such a standardized enterprise, developing countries might introduce their young engineers from the beginning, so as to acquire a full mastery of the plants. Other young colleagues might attend special courses in the European schools of Nuclear Engineering in reactor control and fuel cycle operations.

In this way with a technical-economical enterprise to save precious resources a simultaneous task of great cultural and technological value would be accomplished, particularly for what pertains to fall-outs in bordering fields: chemical engineering, electronics, plant instrumentation, informatics, etc.

Even under this aspect, an international enterprise focusing on small multipurpose reactors might be attentively considered among the developing lines of the eighties. Low-price energy and desalinated water are the goals, as well as a longer duration and a better economy of fossil resources.

ENERGY AND DEVELOPMENT THE ITALIAN APPROACH IN THE SAHEL

ANDREA DI VECCHIA
Department of Cooperation for Development
Ministry of Foreign Affairs
Italy

1. *Introduction*

Energy consumption is different in developing countries (DC) than in the industrialized world, not only in quantitative terms but also in its pattern, structure, and recent evolution. Consumption of commercial energy sources increased sevenfold in DC between 1950 and 1976, as compared with only threefold worldwide. This would not be a negative phenomenon per se if it were not accompanied by severe deterioration in the balance of payments and by the overall stagnation of economic development. The gaps among various DC have also been widening, as reflected in the levels of total energy consumption, as has the even more striking rift between urban and rural areas of the individual countries.

Non-commercial energy sources play a crucial role in DC, alongside the standard commercial energy sources. The demand for the most important non-commercial energy source, firewood, an essential fuel in Africa, is ten times greater than the regenerative capacity of woody plants, which therefore contributes to accelerating the process of desertification.

Thus a paradoxical situation has been created in the DC. It is imperative that they increase energy inputs if they are to continue the process of economic and social development. But all ways of doing so are potentially hazardous: increased importation of energy sources would have negative impact on their balance of payments, while proper exploitation of local resources would demand untenable levels of investment, or wreak havoc with the environment and consequently with the economic system (as is the case for firewood), or both.

Under these circumstances, indiscriminate expansion of energy consumption in DC is unthinkable. Priorities must be established within the process of development, sectors in which a rise in energy consumption can be justified by its potential for setting into motion self-perpetuating mechanisms of growth and economic expansion. The choice of these sectors will depend on the model for development being followed, since clearly emphasis on industrialization versus agriculture, urban versus rural areas, will imply divergent choices of energy sources, technology, and methodological approach.

No single source is valid for all contexts in DC; none can guarantee (as did oil) the satisfaction of a large variety of needs. The search for a specific local solution must therefore begin with the critical examination of all available resources and of actual and potential energy applications, so that both resources and needs can be optimized in a single plan. It must always be kept in mind that energy is only one of many factors in development; making energy more available or its use more rational does not guarantee that development will take place.

2. *Energy and developing countries*

The serious world-wide crisis of 1968 led to the discovery of the "energy problem" in both its aspects: the finite nature of the world's energy resources, and the importance of energy considerations as an economic variable. This new reality, which has often been underscored by catastrophic predictions, has obliged all countries (faced by unstable prices for energy products) to undertake a transition process toward revising their productive structures and their patterns of consumption. The oscillations in fuel prices — generally upward but recently with a substantial drop — have made it yet more difficult to produce valid policies and plants.

Although they were forced to endure a lengthy economic recession, the industrialized countries have in the end been able to deal with the "energy problem" and to make radical changes in their patterns of consumption and their energy technology, through the infusion of massive investments.

Faced by the same dilemma, DC have encountered problems that have been virtually insoluble, or which could be attacked only at the cost of further strain on the weakest elements in their economies. These countries have not only had to reorganize energy consumption and to modernize their infrastructures, but they have had the simultaneous task of increasing their overall consumption so as to be able to continue the process of economic development. It can be seen from Table 1 that energy consumption in DC, while taking off from extremely low levels, has increased twice as fast as in the rest of the world — a differential that is not expected to change.

The pooled energy data of the DC hide a serious phenomenon which is emblematic of the complexities of economic reality: several of these countries have managed to handle the energy transition while maintaining economic development, while the great majority have been plunged into an abysmal crisis. China alone accounted in 1980 for 30% of the total commercial energy consumption of the developing countries, and for 60% of coal use; Brazil, India, and Mexico together made up another 20%. The first twelve DC out of the United Nations list of 131, in fact, absorbed more than 67% of total energy consumption.

Furthermore, while the more industrialized DC have been able to diminish the importance of oil in their energy "mix", many other DC have been unable to follow suit. The most impoverished countries have remained the most dependent on oil, because gasoline engines account for a relatively high proportion of their total consumption.

Another factor influencing the ability of various DC to weather the energy transition is the extremely uneven distribution of energy resources, which leads to a great range of problems and perspectives. The

TABLE 1 - *Consumption and annual increase of commercial energy sources* (World Bank data).

	Absolute value (in millions of Toe)						Yearly increase (in percentage)			
	World			Developing Countries			World		Developing Countries	
	1970	1980	1995	1970	1980	1995	1970-80	1980-95	1970-80	1980-95
Oil	2311	3067	3355	355	626	934	2.9	0.6	5.8	2.7
Coal	1475	1825	2821	298	494	940	2.2	2.9	5.2	4.4
Gas	889	1241	1930	47	95	324	3.4	3.0	7.3	8.5
Hydroelectric geothermal Nuclear	328	611	1423	56	130	396	6.4	5.8	8.8	7.7
Total	5003	6744	9529	756	1345	2594	3.0	2.3	5.9	4.5

major division is between oil-exporting and oil-importing countries. For the former, the explosion of oil prices has meant expansion of their financial resources and consequently the possibility of concrete economic development. They need however to work out development policies which include diversification of exports and economical exploitation of the surplus value of their energy resources, in order for them to avoid patterns of heightened internal consumption that may not imply a corresponding economic development for the entire country.

For the oil-importing DC, on the other hand, the percentage impact of imports on total consumption is important because of the direct effect of rising prices on the balance of payments. More than half of these DC, it should be noted, import over 75% of their total energy needs.

Another basic distinction is to be made between countries with low versus medium incomes both because the poorer DC are less able to reassign funds from other sectors to pay for imports, and because they have more difficulty in obtaining international loans to pay for imports or to develop their own potential energy resources.

Table 2 summarizes the financing that would be necessary to cover the 1995 goals indicated in Table 1. These estimates by the World Bank give a financial dimension to the energy transition in the developing world; over the next decade, 130 billion dollars will be needed per year if projected needs are to be met (half from domestic resources and half from international financing). International funds are particularly necessary for the poorer, least developed countries, which have the most difficulty obtaining them, and where the local market is less capable of providing even raw materials.

These projected levels of investment are far greater than present prospects. The input to DC from international sources did grow from 9.7 billion dollars in 1975 to 15.8 billion dollars in 1980, but this remains a drop in the bucket: only 25% of the sum considered necessary by the World Bank. It is therefore inconceivable that the existing financial gap will be closed in the near future, especially since the current tendency is for freezing of the financial resources made available to DC for development purposes.

Although these calculations have been useful for sketching the severity and scale of the "energy problem", they point to no possible solutions and, what is worse, are liable to imply incorrect or at least distorted conclusions, especially as far as the least developed countries (LDC) are concerned.

TABLE 2 - *Investments needed between 1982 and 1992 to develop commercial energy sources in developing countries* (World Bank - millions of U.S. dollars).

	Low-income DC	Medium-income DC Oil Importers	Oil Exporters	All DC	Annual average 1982-92
Electrical energy					
Hydroelectrics	74.4	132.2	31.8	238.4	21.7
Nuclear	6.3	40.8	6.1	53.2	4.8
Geothermal	0.1	4.3	2.1	6.5	0.6
Thermal	43.2	75.8	39.7	158.7	14.4
Transmission and distribution	49.9	101.8	49.9	201.6	18.3
Subtotal	173.9	354.9	129.6	658.4	59.8
Oil					
Exploration	21.2	48.9	99.1	169.2	15.4
Development	43.2	32.4	195.9	271.5	24.7
Other	2.5	6.0	16.7	25.2	2.3
Subtotal	66.9	87.3	311.7	465.9	42.4
Refineries	30.8	52.8	39.7	123.3	11.2
Natural Gas					
Exploration, development, transmission and maintenance	17.5	16.8	30.2	64.5	5.9
Export	0.0	3.0	6.2	9.2	0.8
Internal distribution	4.3	4.7	7.4	16.4	1.5
Subtotal	21.8	24.5	43.8	90.1	8.1
Coal	55.2	27.2	6.3	88.7	8.1
Total	348.6	546.7	531.1	1,426.4	129.7

It is clear that the energy problem must be dealt with comprehensively as a unified issue. In practice the qualitative/quantitative different accuracy of the data regarding commercial versus non-commercial energy sources and the needs of city versus country, have led to a tendency to split the analysis according to these various divisions. This split reflects the broader one between market economy and subsistence economy. In effect, the methodological difficulties of accounting in a single model for the extremely local and specific parameters of a subsistence economy and the macroeconomic parameters of a market economy, which coexist in the economies of DC, have meant that two independent models have been theorized simultaneously, ignoring the unity of human activities. The resulting separation of commercial from non-commercial sources and the emphasis of analysts on historical consumptions and trends have led various theoreticians to favor commercial sources as more consonant with classical schemes of economic analysis.

Because of these factors, greater weight has historically been given to DC with a considerable industrial base and a proportionately greater urban population. For one thing, the industrial and market structures of various countries have been lumped in analysis, and, for another, most of the subdivisions of commercial energy sources concern the production and distribution of electrical energy or road transportation, all costs which are much more significant in the urban setting.

If such an approach is followed, any conclusions as to priorities for financing, which are extrapolated uncritically to the LDC, would be biased in favour of the development of urban areas within their fragile economic systems. In reality, models of development via rapid industrialization (following the example of the industrialized world) have been largely abandoned. It will therefore be necessary to rethink the concept of "bankability", which can no longer be based abstractly on economic calculations but must also vary according to other factors, including the satisfaction of basic needs and the dynamics of development.

For the LDC in particular a new approach must be sought to the energy problem, one which can better allow a bird's-eye view of the overall model of development. The low per-capita income in these countries is a direct index of the absence of industrial structures and of appreciable natural resources, and therefore of the low consumption of conventional energy sources per inhabitant. It is precisely these lowest levels of energy consumption that must be increased at a faster rate than in the other DC, an imperative which becomes even more complicated by the great difficulty these countries have in entering the international financial system, and by their equally pressing need to obtain financial aid directly geared to guaranteeing their basic needs.

3. *Energy and Africa*

The need to change approach is particularly urgent in Africa, where energy policies and aid priorities have until now been distant from the real needs of development.

More than elsewhere, the rural world is important in Africa: it absorbs approximately 80% of the population.

United Nations data indicate that in Africa one person out of two lives in absolute poverty. This means that out of 450,000,000 inhabitants of the continent, 225,000,000 (165,000,000 of whom live in rural areas) are living in what the United Nations classifies as absolute poverty. The connection between mass poverty, hunger, malnutrition, and widespread agricultural underdevelopment is quite close. Today a vast majority of Africans still depend for their food needs on the produce of their own farms. For this huge slice of the population, the threat of crop failure and of food shortage is constant.

From the point of view of an individual country, the food problem obviously depends on the course of agricultural production and on its limited capacity for importation. The solution to the problem of food security, in a Third World inhabited largely by farmers and their families, depends in the last analysis on local agricultural production not only to ensure that the country as a whole will be fed, but also to fight hunger among the rural population that is the most exposed to it.

It is impossible to imagine, given a present situation of growing constraints on their balance of payments, how the DC can obtain "food security" by counting on quantitative leaps in imports. Increased local agricultural production is thus a vital aspect of their food security and their national development, especially since an industrial boom capable of generating sufficient funds to cover massive grain imports is unthinkable in these countries.

In Africa, a serious crisis of the agricultural sector has transformed the self-sufficiency of two decades ago into a severe food deficit. The situation has been made even more serious by the halt in development which has followed the energy crisis. Per capita food production in Africa fell by an average of 0.7% per year during the 1960's and by 1.1% per year during the 1970's. According to FAO predictions, African countries will be obliged by 2000 to import foodstuffs worth more than ten times the quantity of their agricultural exports, if they are to fill their food needs.

A series of negative factors aggravate the "energy problem" in Africa, ranging from particularly rapid population growth, to a relative lack of natural resources, to a dearth of economic structures, to the priority that the area must give to the satisfaction of primary needs such as food. Among the 38 subsaharan countries with population over one million, only four export oil. Another, Cameroon, imports oil but has substantial potential resources of its own. Of the remaining 33, 21 possess moderate quantities of natural resources; four of these import less than 25% of their global needs, two import 26-50%, six between 51 and 75%, and nine more than 76% of their consumption. The twelve countries most impoverished from the point of view of energy resources include two which nonetheless import less than 25% of their total needs, and two which import 51-75%; the remaining eight import more than 75%.

Non-commercial sources, especially firewood, are extremely important in subsaharan Africa for energy in rural areas. At present half the world's population lives in areas where firewood is scarce, and no serious steps have been taken to secure future needs. Wood gathering razes 10,000,000 hectares of forest every year, a process of desertification which is accentuated in arid or semiarid regions.

Unfortunately most rural inhabitants can satisfy their basic energy needs (cooking, for example) only by using energy sources such as wood, since commercial sources are beyond their means. It has been calculated that even if the demand for firewood can be reduced by 20-30% by conservation compaigns or by substituting other sources, it will be necessary to plant at least 50 billion hectares of new forest before the year 2000 if resources are to be brought into line with consumption by the end of the century. This goal would require an increase over the present rate of reforestation of fivefold worldwide and of fifteenfold for subsaharan Africa.

The particularly generalized failure of industrialization in this continent, the deterioration of the agricultural production system, the falling prices of natural resources and agricultural exports on the international market, and the scarcity of oil resources have led, in the last few years, to a drastic rethinking of the development model appropriate to African social and economic realities. The Lagos plan and the Ottawa strategy are typical reflections of a new consciousness of the limits and potential of development, and of the priority that must be assigned to satisfying basic needs, especially for food. Thus the central role of the rural world in guaranteeing food security within each country is becoming widely recognized.

If then an energy policy is to be defined with greater attention to its ability to approach the problem of food security, it is useful to concentrate on the data of the economically weakest countries (the LDC), which are less capable, on the one hand, of obtaining financial, human, and technological resources for their development and, on the other, of dealing with unpredictable catastrophes such as floods and drought. With this perspective, an area of particular interest for Italian cooperation, and on which this analysis will now concentrate, is the Sahel region, which includes Cape Verde, Chad, Gambia, Mali, Mauritania, Niger, Senegal, and Upper Volta. In the past 18 months a maxi-project of cooperation has been instituted, for a total of $ 500,000,000, with the aim of sustaining these countries in their drive toward food security. While only six of these eight countries belong to the group of the LDC, drought has become such a fundamental force in the entire Sahel that its ecosystem is threatened with an irreversible destruction that would have disastrous effects on the population.

Tables 3 and 4 report the total population, its rural component, and the consumption of commercial energy sources in the region as a whole and in LDC countries, while Table 5 compares the above data to those regarding the use of non-commercial energy sources.

The first reflection arising from contemplation of these figures is that the economic crisis of underdevelopment is particularly profound in subsaharan Africa, where 24 out of 36 of the world's poorest countries

TABLE 3 - *Population and commercial energy consumption in Africa* (1979).

	POPULATION			COMMERCIAL ENERGY CONSUMPTION	
	Total Population	Rural Population	Rural Pop. %	Total Tce × 1000	kg of coal equivalent per capita
Subsaharan Africa	343,900,000	271,681,000	79.0	44019.20	128.1
LDC	121,123,760	103,927,140	86.0	5464.95	45.1
other DC	222,776,240	167,753,860	75.3	38544.25	173.1
Sahel	30,211,740	24,987,890	82 7	2608.52	86.3

TABLE 4 - *Population and commercial energy consumption in African LDC* (1979).

	Population			Commercial Energy Consumption	
Country	Total Population	Rural Population	Rural Pop. %	Total Tce × 1000	kg of coal equivalent per capita
Benin	3,377,000	2.850,100	84.4	229.64	68
Botswana	936,600	694,960	74.2	76.80	82
Burundi	4,021,000	3,779,740	94.0	68.36	17
Cape Verde	295,260	190,740	64.6	73.81	250
Central African Rep.	2,000,000	1,180,000	59.0	110.00	55
Chad	4,401,000	3,714,440	84.4	105.62	24
Comoros	270,000	222,210	82.3	15.93	59
Equat. Guinea	245,990	181,790	73.9	27.30	111
Ethiopia	30,900,000	26,265,000	85.0	618.00	20
Gambia	493,200	396,530	80.4	65.60	133
Guinea	3,537,000	2,985,230	84.4	307.72	87
Guinea Bissau	777,250	619,470	79.7	54.41	70
Lesotho	1,216,820	1,138,940	93.6	208.08	171
Malawi	5,547,000	5,130,970	92.5	388.29	70
Mali	6,308,320	5,248,520	83.2	189.25	30
Niger	5,536,000	4,844,000	87.5	265.73	48
Rwanda	4,819,320	4,616,910	95.8	144.58	30
S. Tome & Principe	80,000	65,840	82.3	20.00	250
Sierra Leone	3,400,000	2,550,000	75.0	302.60	89
Somalia	3,406,000	2,472,760	72.6	265.67	78
Togo	2,505,000	1,998,990	79.8	293.08	117
Uganda	12,800,000	11,264,000	88.0	499.20	39
United Rep. of Tanzania	18,000,000	15,840,000	88.0	954.00	52
Upper Volta	6,251,000	5,675,910	90.8	181.28	29
Total	121,123,760	103,927,140	86.0	5464.95	45

are found and where these LDC account for more than one-third of the total population.

A second consideration is that the individual inhabitant must be placed in control of his own development here even more than elsewhere: in the poorest countries and in the Sahel, energy policy must concentrate on the rural world. It is illogical, except in exceptional cases, to weigh down

TABLE 5 - *Population and energy consumption in the Sahel.*

Country	Population			Commercial Energy Consumption		Non-Commercial Energy Production		Non-Commercial Energy Consumption	
	Total Pop.	Rural Pop.	Rural Pop. %	Total tce ×1000	kg coal equivalent per capita	Total tce ×1000	kg coal equivalent per capita	Total tce ×1000	kg coal equivalent per capita
Cape Verde	295,260	190,740	64.6	73.81	250	56.1	190	55	190
Chad	4,401,000	3,714,440	84.4	105.62	24	2535.5	576	1300	286
Gambia	493,200	396,530	80.4	65.60	133	257.1	521	242	428
Mali	6,308,320	5,248,520	83.2	189.25	30	9401.7	1490	1636	286
Mauritania	1,419,960	1,040,830	73.3	262.69	185	198.3	140	348	237
Niger	5,536,000	4,844,000	87.5	265.67	48	983.6	178	1090	237
Senegal	5,507,000	3,876,930	70.4	1464.60	266	862.2	157	1424	286
Upper Volta	6,251,000	5,675,900	90.8	181.28	29	2263.2	362	2030	335
Total	30,211,740	24,987,890	82.7	2608.52	86	16557.7	548	8125	269

the finances of the poorest countries with investment-intensive projects which benefit a small minority of the population.

The rock-bottom per capita consumption of commercial energy sources in the Sahel indicates that not only are energy-intensive industrial processes virtually absent, but there is even gross underdevelopment of transport systems.

The reported data substantiate the preponderance of non-commercial sources in supplying energy to the Sahel as a whole, but great inter-country variation and local peculiarities must be taken into account if one is to plan means to improve the situation. The low percentage of non-commercial sources in Cape Verde, for example, derives from the absolute lack of natural resources as well as from the inauspicious conformation of the national territory (which is divided into several small islands). Another example is the low consumption of firewood in Niger and Mauritania, related to the large percentage of their land area which is desert.

The close link between firewood use and climatic conditions is clear from the list of energy sources in the Sahel countries. Niger and Mauritania constitute the northern portion of the Sahel along with Mali and Chad but do not share the Soudanese climate found in parts of the latter two countries. Senegal is on the same level of consumption as Mali and Chad, but its own northern half is undergoing rapid ecological deterioration. Particular conditions hold for Upper Volta, endowed with scattered patches of generous vegetation, and for Gambia with its completely Sudanese climate.

It is also of interest to compare firewood consumption with potential production. Where the distribution is similar for population and for forest resources, as in Cape Verde, Gambia, and Upper Volta, the two data are superimposable, while where the desertification process is advanced (Mauritania, Niger, and Senegal) production lags far behind demand. In Chad and Mali the distribution of persons and resources are dissimilar, a large proportion of the population being located in arid areas far from the zones which are relatively rich in vegetation; here production well outstrips demand but is difficult to exploit because transportation costs exceed the market value of firewood.

This section has brought out the difficulties in defining energy policy and planning intervention, not only worldwide or over an entire continent, but also in a single region. It is possible however to overcome these obstacles through a methodology and an approach that are general but which allow explicitly for the possibility of particular local conditions.

4. *Italian Cooperation*

The Italian government has recognized the importance of energy availability for development in the Third World, and in the last analysis also for the fight against hunger, by assigning the energy problem to a level of priority second only to agriculture in Italian cooperation. Since the 1981 Nairobi Conference, the energy policy of the Department of Cooperation for Development has evolved in the direction of integrating energy projects to a greater extent in the overall development process.

At the time of the Nairobi Conference, it was recognized that the energy problem had to be approached, at a first approximation, in the context of broad regional planning. Thus the idea of "large demonstration projects" arose: integrated energy projects which took into account and optimized the use of all the energy resources available in a given area. While constituting a step forward in the development of methods of energy planning, this approach tended to give excessive weight to "perfect" technical solutions instead of those which might be more appropriate to local social and economic needs.

Building on this experience and on its limitations, during the planning of the Italian Sahel Initiative an attempt was made to define specific sectorial policies — including those regarding energy — as a subdivision of the general approach of the entire Initiative.

As an overall plan, the Sahel Initiative has been designed to take into account the peculiarities of each country while guaranteeing a common regional plan of action. One prime general objective, given the drawing off of wealth from a progressively pauperized countryside and its concentration in the cities, is to combat this process by encouraging stable economic integration between urban and rural areas. The resulting restructurization of the productive base is intended to increase rural productivity and income while motivating the cities to provide services for the countryside and markets for its products.

The success of such a project is necessarily predicated on its adaptation to the local cultural systems of values and to the level of social-economic development in the country — which means the considered use of appropriate technology.

In designing the Sahel Initiative, articulation of projects on three levels of intervention, consistent and intercoordinated with each other, promised to be the most fruitful overall organization. The first level is that of one or more local areas selected in each country for a plan of integrated rural development (IRD) covering aspects from food production to commercialization to infrastructures to health. On the national level, particular attention is paid to the structural and institutional bottlenecks that could reduce the impact of the IRD programs on national development. On the regional level, finally, various programs of interest to all the Sahel countries have been set up, with the perspective of reinforcing their economic integration and South-South cooperation.

The decision to concentrate on limited geographic areas within each country grew out of the need to attack simultaneously on many fronts the various forces impeding development; the geographical limitation is intended to allow a "threshold" effect to be achieved by a given financial investment, to spark dynamics of development which can then be managed by the local population. A level of investment greater than the area's absorption capacity could have a negative effect on development, so limits have deliberately been set on the number and scale of interventions organized in each IRD project.

Interventions in the energy sector have appeared as specific projects on a national and regional level. In the designated local areas, on the contrary, they have constituted an integral part of the IRD programs, in order to meet a variety of specific needs as part of a development plan rather than at random. Reforestation projects, for example, fulfill their purpose of reestablishing an equilibrium between the supply and the demand for firewood not only by instituting village woodlots but also by the extensive planting of windbreaks (which are independently useful in controlling wind and water erosion) and orchards, as well as the experimental introduction of improved wood stoves. These projects have been further articulated according to local characteristics: level of soil deterioration, population density, etc.

By widely disseminating the use of animal traction, the Italian Initiative aims to obtaining a qualitative technological leap in the agricultural system by substituting animal for human labor. Production is expected to benefit directly thereby, as farmed surface expands and consumption of human resources contracts, but there is also an indirect boost to the national economy as a whole when appropriate technological support systems are developed (farm factories, repair shops, etc.).

Urban-rural integration is tackled by encouraging the growth of major villages and their transformation into service centers for the surrounding territory. Many end-uses growing out of this transformation require electrical energy, whether via microgrids or using individual generating plants for each application. Local priorities will determine whether emphasis is to be placed on social end-uses (e.g., dispensaries) or productive ones (e.g., transformation of agricultural products). Neither type can be totally neglected, as both are essential to development, but errors in the direction of oversizing the power plants can generate unmanageable recurrent costs, with the risk that the entire plant will be abandoned.

For small-scale electricity generation (hundreds of kW), technological solutions different from standard oil-fueled diesel engines can be economically interesting, especially in isolated areas. Minihydraulics and biogas production can both be useful, while investment in photovoltaic systems may be justifiable for certain low-power applications. Priority should be given in such settings to reliability and to minimal need for maintenance, even at the price of minor losses in efficiency.

On a national level, techniques of energy conservation have been emphasized, especially through improving electricity production and distribution, and by building and maintaining the roads that are vital for fuel transport. These measures not only have a direct impact on the balance of payments, by reducing energy imports, but the resultant interdependent urban-rural network also allows faster and cheaper circulation of products as well as the development of transformation activities.

Countrywide personnel retraining has also been undertaken, in order to strengthen various national institutions in their own planning and outreach capabilities; here extreme care has been necessary to avoid uncontrollable increased budgets for the recipient countries.

Regional intervention, finally, has emphasized the possibility of integrating energy resources on both sides of national boundaries.

In conclusion, we have chosen to base the Italian Sahel Initiative on the needs of the local population rather than a priori technological considerations. This approach has not only led to satisfactory short-term results but also has the potential for inspiring and organizing the kind of direct grassroots local control that can keep its fruits functioning long after the end of each specific project.

Our methods are not to be blindly replicated in other geographic areas, but they do point out a methodology for cooperation planning: to define articulated and coherent development programs instead of showers of disconnected "aid" projects that may be easier to carry out but which are bound to fail to guarantee any real basis for development.

THE ROLE OF THE WORLD BANK IN ASSESSING ENERGY ISSUES AND FINANCING PROJECTS IN DEVELOPING COUNTRIES

JEAN-LOUP DHERSE
World Bank
Washington D.C., USA

1. *Background*

The share of oil importing developing countries (OIDCs) is projected to increase over the period 1980-95 in each of the main sources of primary energy, in both production and consumption. In oil, OIDCs account for 59 percent of the world increase in consumption and 28 percent of the increase in production; if one includes the oil exporting developing countries, their combined share exceeds the global increase, more than offsetting declines in the rest of the world.

Underlying these projections is the assumption that *increases in energy consumption* will be slower than historical rates in both developing countries and the world as a whole. In developing countries, it is assumed that such a slowdown is taking place despite a build-up of economic growth rates to their historical levels, to average nearly 5.5 percent per year in 1985-95. For the oil importers, the net impact of these adjustment measures is to reduce the share of oil imports from 44 percent of their commercial energy consumption to about 28 percent in 1995. Nevertheless, the actual volume of their oil imports will need to continue growing, from 295 million toe in 1980 to 386 million toe in 1995. These increases are needed despite a massive effort to increase commercial energy production in OIDCs by nearly 150 percent from 382 million toe in 1980 to 950 million toe in 1995.

The *investments required* to achieve such a large increase in energy production are correspondingly massive. We estimate that in the low-income countries (including China) and the middle-income oil importers, the annual investment needs are of the order of $80 billion, of which about $ 25 billion will require foreign exchange financing.

Foreign exchange flows to low income countries are limited by the slow expansion of official credits — particularly concessional flows. These countries at present rely on multilateral and concessional bilateral flows for about 80% of their external public borrowing for energy. Middle-income countries were until recently able to obtain half of this borrowing as export-related and private financial flows. The financing of oil and especially gas projects in OIDCs will pose a major problem. Their estimated foreign exchange requirements of $ 10 billion a year are about equal to the current pubicly-guaranteed financing flows for the whole energy sector in these countries.

It is important to stress that the projected investments are not only necessary and technically feasible, but also remain economically attractive even under a wide range of oil prices. Most of them would still be advantageous to developing countries even if the international oil price were to settle at a lower level (of say $ 25 per barrel in 1983 dollars).

The important *components of energy strategy* in OIDCs:

— Energy efficiency;
— Fuel substitution;
— Petroleum exploration;
— Resource mobilization.

In each of these areas one also encounters the need to overcome human resource constraints.

Studies have shown that in the *energy-intensive industries*, many plants in developing countries consume 10 to 30 percent more energy per unit of output as best international practice and some consume over twice as much. Significant savings of up to 15% are possible in the *transport sector*, accounting for about 20-40 percent of developing countries' petroleum use.

Electric power system: While the optimal level of *transmission and distribution losses* is generally below 10 percent, the actual loss ratios are higher in almost all of the 76 countries for which we have reviewed the data recently, rising to over 30 percent in some countries.

Pricing energy at its opportunity cost: In the oil importing developing countries, increases in the international price of oil have generally been passed through promptly to consumers, with the result that the weighted average domestic retail price of *petroleum products* is higher than import parity in most cases. But the reverse is true in a number of countries. The appropriate adjustment of *electricity tariffs* in developing countries has been less successful: only 18 of 33 countries surveyed recently have increased their tariffs in real terms since 1974.

Generally, the greatest potential for reducing energy costs through *substitution* lies in replacing heavy fuel oils with natural gas and with coal, in electric power and in industry. Electric power supplied 31 percent of the commercial energy used by oil importing developing countries in 1980 and will account for over half of their incremental commercial energy consumption in 1980-95. Two thirds of the increase in power generation on OIDCs is projected to come from primary sources (mainly hydro and some nuclear) while the fuel mix of thermal power generation is projected to change rapidly. Coal will replace oil, to take up a dominant place, accounting for 78 percent of thermal generation in 1995. Though total power generation increases two and a half times, the volume of oil used is projected to decline. If the generation mix remained the same as in 1980, the additional oil required by 1995 for thermal generation would raise the oil demand in OICDs by over 20 percent above projected levels.

Exploration for petroleum in OIDCs is short of needs in spite of some recent improvement. The gross additions to their oil reserves have lagged behind production rates, and are only a small fraction of the additions elsewhere. Moreover, most of the additions have been in only three countries: Argentina, Brazil and India. Exploration activity in non-producing countries is at a low level.

2. *Role of the Bank*

The principal objective of the World Bank's energy program is to assist developing countries to define and implement appropriate energy sector strategies to meet the urgent needs. The urgency and the magnitude of structural adjustments necessary in the energy transition imply much greater attention to policy and management issues, preinvestment studies to formulate better strategies for energy supply and utilization and the mobilization of financing for the large investments required. The Bank has responded to these needs and attempted to function as a catalyst in promoting strategy formulation, policy reform and institutional strengthening; and in mobilizing external sources of technology and finance to implement effectively the changed investment priorities in developing countries. It has expanded and diversified its energy lending and is putting greater emphasis on assisting borrowers to introduce new technologies, strengthen institutions and improve the policy framework in the energy sector.

This work has made an important contribution in helping to define "energy" as an integrated sector in many developing countries. Because of the unfamiliar issues posed by a sudden change in relative costs of different forms of energy there was a clear need for assistance to developing countries in evaluating their main energy issues and options. To meet this need, the Bank collaborated with UNDP in launching the *Energy Sector Assessment Program* that is designed also to serve as a framework for further multilateral and bilateral assistance in the sector.

Energy assessment reports have been completed for 29 countries and are under way in an additional 19. These reports analyze the scope for changes in pricing. institutional arrangements and other policies to encourage domestic energy production and the more efficient use of energy. They also provide a framework for multilateral and bilateral assistance to the energy sector. An important feature of the assessment reports, which are prepared by in-house staff and experts brought together for this specific purpose, is that the final reports are circulated to all the major donor agencies and can therefore be used as an important tool for aid coordination in the energy sector. For example, they have been used at meetings of Consultative Groups (Uganda, Sudan, Nepal, Bangladesh, Indonesia) and the UNDP-sponsored Round Tables (Burundi). More important is the fact that the governments concerned have found these reports to be useful and are making extensive use of the advice provided by the assessments.

A related program, the *Energy Sector Management Assistance Program* (ESMAP) has also been developed more recently with the UNDP to help countries implement the main recommendations of the Assessment Reports. The Program provides staff and consultant assistance to define and justify the policy. investment and technical assistance options identified by the assessments so that national policy makers, private investors and official assistance agencies can act more rapidly to implement them. A good example of ESMAP involvement in project preparation is the work carried out on improving the efficiency of wood energy use in the tobacco curing industry in Malawi.

In addition to project preparation, the ESMAP can also assist in the analysis of institutional and policy options and the definition of technical assistance requirements for establishing an effective energy sector management capability. As with the Energy Assessments Program, ESMAP reports are also circulated to all interested donors and can be used as a basis for programming their assistance efforts. In the first eight months of the ESMAP program, which was started in April 1983, 26 specific activities had been completed or were underway in 13 countries.

The Bank's *Structural Adjustment Lending* also frequently provides the mechanism for discussing and resolving important energy sector issues. Most of the Structural Adjustment Loans approved in FY83 include some emphasis on the restructuring of energy policy and programs. This emphasis is expected to continue because, for many developing countries, changes in energy supply and demand patterns will effectively determine the success of their overall adjustment efforts.

Bank project selection is based on a *review of sector objectives*, priorities and investment options. Ensuring that the project's design represents the least-cost solution frequently involves an analysis of alternative development options for the energy supply system as a whole, because of strong interlinkages and complementarities that exist among individual projects. Special efforts are also made to ensure that the project design will help transfer new technology to the borrower, which can be applied to benefit the sector as a whole. At the project level, this entails the design of implementation arrangements which will create a corps of managers to maintain, operate and expand the facilities provided under the project. Many projects provide for training and technical assistance to address institutional weaknesses: the total volume of technical assistance provided under Bank energy projects in FY83 was of the order of $ 460 million.

The Bank's sector advice is backed by a significant amount of *project lending*, making it the single most important official source of external capital for energy development in the developing countries. Its energy lending has risen from US $ 1.5 billion in FY79 to about US $ 3.0 billion in FY83, (including US $ 343.8 million in concessional IDA credits). Further, the Bank has made a special effort in the energy sector to mobilize *additional external financing* and promote opportunities for direct private investment. During FY79-83, the US $ 12.9 billion of Bank lending for energy was associated with another US $ 12.0 billion of co-financing from other external sources. To further stimulate the interest of co-lenders, the Bank has recently introduced a trial program of *new cofinancing instruments* (called "B" loans) whereby the World Bank participates directly or accepts a contingency commitment in a commercially syndicated loan.

Although most of the Bank's energy lending has been traditionally in the power sector, a key feature of the Bank's energy lending in recent years has been the *increase in lending for oil and gas* exploration and development, from a loan amount of US $ 112 million in 4 projects in 1979 to US $ 1 billion in 17 projects in 1983. In this period, the Bank has supported petroleum projects in 36 countries.

An innovative feature of the Bank's petroleum lending has been the *exploration promotion projects* which are designed to accelerate the competitive offering of new acreage to the international petroleum industry on reasonable terms. They involve expenditures of about US $ 5-10 million on compilation of promotional data, and training and advice in technical, legal and contractual areas. There are now 29 such projects under way, with 13 of them having reached the negotiation stage. The promotional activities of the Bank have contributed directly to the signing of exploration/production agreements (in Equatorial Guinea, Liberia, Madagascar, Mali, Mauritania, Pakistan and Tanzania).

The Bank has also been ready to support the *direct exploration and development* activities of national oil companies when it is convinced that this is an appropriate feature of the country's optimal sectoral and national development strategy, as is the case when the priorities of the international petroleum industry do not match the priorities of the country. Countries where the Bank has supported exploratory drilling by national oil companies are Bolivia, Egypt, India, Jamaica, Morocco, Philippines, Portugal, Tanzania, Turkey. In four of these nine countries, there have already been positive results leading to the discovery or confirmation of about 700 million barrels of oil equivalent, of which 85% is natural gas and associated liquids. In the other cases exploration is still under way.

While the need and the scope for increasing the scale of Bank involvement in the energy sector is clearly considerable, there is a definite *resource constraint*. The Bank's energy lending cannot exceed about 25 percent of its total lending without curtailing its lending for other high priority investments below acceptable levels. Applying this guideline, the Bank's energy lending in FY83-87 is unlikely to exceed approximately US $ 4 billion a year on average (1983 dollars).

ENERGY FOR DEVELOPING COUNTRIES AND INTERNATIONAL CO-OPERATION

MUNIR AHMAD KHAN
Pakistan Atomic Energy Commission
Islamabad, Pakistan

1. Introduction

Energy is a vital issue for both developed and developing countries. While the energy crisis resulting from a sharp rise in oil prices during the 1970s and growing realisation about rapid depletion of global petroleum resources have adversely affected the economies of almost all countries, the plight of the resource-poor developing countries is particularly appalling. These countries, being at the lower rungs of the economic development ladder, have correspondingly low levels of energy consumption but would need large inputs of energy in the coming years in order to support their much needed industrial and other socio-economic development activities and for satisfying the growing aspirations of their rapidly increasing population. Most of them are acutely short of indigenous energy resources, lack investment capital as well as technological know-how for expanding domestic energy resources base and have become heavily dependent on imported energy. Due to a tenfold increase in the price of imported oil over the last one decade, the cost of energy imports is now putting a crippling burden on their economies; the energy import bill in several of these countries now exceeds 50%, and in some cases even 100%, of their total earnings from merchandise exports. As a result, a number of developing countries have, in order to finance their developmental activities, been forced to borrow quite heavily from international sources, generally at high interest rates. With their 1982 debt (*) stand-

(*) The present estimated debt is nearly $ 700 billion [16].

ing at 550 billion dollars (equivalent to 23% of their annual GNP), the low- and middle-income developing countries are spending about 5% of their combined GNP or 21% of their export earnings on debt servicing alone. These financial difficulties have seriously affected their economic growth, which now barely exceeds their annual population growth rate.

There are glaring socio-economic disparities between the developed and the developing countries which, if left unattended, may have serious implications for future global security and world peace. In order to narrow the gap between the "haves" and the "have-nots" it will be necessary to increase significantly the pace of industrial and economic development in the developing countries, which in turn will call for much expanded reliable supplies of commercial energy to these countries at reasonable costs. Difficult though it may appear, it is not an impossible task. The world has a sufficiently large stock of conventional and unconventional energy resources which, if used judiciously in combination with new energy technologies, may adequately meet the future energy requirements of both the developed and developing countries in a sustainable way. What is really needed is an environment of goodwill and co-operation between the developed and developing countries leading to a mutual sharing of both resources and technologies in an equitable manner with the welfare of mankind as a whole being the foremost objective.

This paper reviews the current energy situation in the developing countries with respect to both the level of consumption and resource availability, and compares it with that in the developed countries (**). It then looks into the cost of energy imports in the resource-deficient developing countries and presents an overview of the financial difficulties of the low- and middle-income developing countries. After giving a brief résumé on the expected growth of energy demand in the developing countries, the paper analyses the prospects of future energy supply in these countries based on different energy options and underlines the crucial role which nuclear power can play in offering a technologically and economically viable alternative to dependence on imported oil. It

(**) The developed countries in the context of this paper are the market economy industrialised countries and the nonmarket economy countries of Eastern Europe. The developing countries comprise Low-income countries, Middle-income countries and High-income oil exporters; Low-income countries are those with GNP/Cap in 1981 less than U.S. $ 410, and High-income oil exporters consist of Bahrain, Brunei, Kuwait, Libya, Oman, Qatar, Saudi Arabia and United Arab Emirates. Taiwan and South Africa are not covered in any group.

analyses the current difficulties in international co-operation in the nuclear field emanating from undue linkage between nuclear power and nuclear weapon proliferation and restrictive policies of the developed countries in the transfer and sharing of nuclear power technology with the developing countries. It is argued that the development of nuclear power under the IAEA safeguards would provide adequate guarantees about non-proliferation and, at the same time, strengthen the energy base of the developing countries. The paper recommends possible measures for enhancing international co-operation in the energy field as a whole to provide enhanced energy security for both the developed and developing countries.

2. Energy Situation of Developing Countries

2.1. *Consumption*

The level of commercial energy consumption in the developing countries is very small compared to that in the developed countries. A large fraction (75%) of their population still lives in rural areas and relies heavily on use of noncommercial fuels (firewood, bagasse, dung, etc.) for household needs and draft power for farming and irrigation activities. In spite of massive effort on rural electrification and provision of electricity to urban poor, less than 20% of the population actually has electricity connections in their households. In most of the developing countries, industrial activity is extremely rudimentary and public transport systems abominably weak while private cars are still a luxury afforded by less than 1% of the population. Table 1 compares the levels of per capita consumption of total commercial energy and electricity in different groups of countries. Also listed in the Table are the corresponding figures for population and per capita GNP. The large imbalance in the global energy consumption pattern is clearly visible. The average annual per capita consumption of commercial energy and electricity in the developing countries is only about one quarter of the world average, one-tenth of the average for the developed countries and one-twentieth of that of North America. The average figures for low-income developing countries, which constitute 2/3rds of the developing country population, are only 1/3rd of those for the developing countries as a whole. Thus, as seen in Table 2, the developing countries constituting about three quarters

TABLE 1 - *Population, per capita GNP, and per capita consumption of commercial energy and electricity in 1980.*

	Population (billion)	GNP/Capita ($-1980)	Per Capita Consumption Commercial Energy (TCE)	Electricity (KWH)
Developing Countries	3.27	680	0.58	370
Low-income				
Oil Importers	1.20	237	0.17	130
Oil Exporters	0.98	290	0.64	308
Middle-income				
Oil Importers	0.58	1,544	1.11	908
Oil Exporters	0.50	1,164	0.80	395
High-income				
Oil Exporters	0.01	12,630	3.45	2,068
Developed Countries	1.09	8,304	6.62	6,268
Market Economy	0.71	10,330	7.08	7,180
(North America)	(0.25)	(11,243)	(11.33)	(10,822)
Nonmarket Economy	0.38	4,478	5.75	4,543
World	4.36	2,594	2.07	1,850

Source: Based on Ref. [3, 5, 13].

of the world population are responsible for only 20 percent of world commercial energy consumption, roughly in proportion to their share in gross world product. Judging from the past experience of the developed countries as well as that of the developing countries themselves in the recent past, the Third World countries will have to substantially increase their level of energy consumption if they are to achieve a reasonable economic growth in step with their urgent development needs. Still, as indicated by various international studies [1-3], the large disparity in per capita consumption of energy in the developed versus the developing countries is likely to continue well into the next century.

2.2. *Resources*

There is a widespread misconception that the developing countries are richly endowed with conventional energy resources. The fact is that the energy resource base in most of the developing countries is extremely limited. This becomes quite evident from Table 3, which summarises the present status of proven fossil fuel and uranium reserves and hydro potential in various groups of countries. The developing countries, which represent about three-fourths of the world population, account for only 36% of the proven global reserves of fossil fuels, 25% of those of uranium and 65% of the technically exploitable hydro potential. If such known occurrences of coal, heavy oil and oil shales, that at some time in the future may acquire an economic value, were also to be taken into account, the known fossil fuel resource potential in the developed countries would amount to 10,000 billion tons of coal equivalent (TCE) as against 2500 billion TCE in the developing countries [4]. The energy resource situation of both the oil importing and the low- and middle-income oil exporting developing countries is particularly precarious. These two groups of countries with 41% and 34% share in global population

TABLE 2 - *Shares of developing and developed countries in global population, GNP, and commercial energy consumption in 1980* (in percent).

	Population	Gross World Product	Commercial Energy Consumption
Developing Countries	74.9	19.6	20.9
Low-income			
Oil Importers	27.5	2.5	2.2
Oil Exporters	22.4	2.5	6.8
Middle-income			
Oil Importers	13.2	7.9	6.9
Oil Exporters	11.5	5.1	4.2
High-income			
Oil Exporters	0.3	1.6	0.8
Developed Countries	25.1	80.4	79.1
Market Economy	16.4	65.4	55.4
Nonmarket Economy	8.7	15.0	23.7
World	100	100	100

Source: See Table 1.

TABLE 3 - *Proven reserves of fossil fuels and uranium, and technically exploitable hydropower potential.*

	Fossil Fuels Petroleum (10^9 TCE)	Fossil Fuels Total (10^9 TCE)	Uranium (10^3 Tons)	Hydro Potential (10^3 MW)
Developing Countries	148	297	448	1,498
Low-income				
Oil Importers	2	26	218	291
Oil Exporters	5	104	N.A	379
Middle-income				
Oil Importers	3	25	179	590
Oil Exporters	69	73	51	237
High-income				
Oil Exportors	69	69	—	1
Developed Countries	77	521	1,355	778
Market Economy	28	326	1,355	533
Economy	49	196	N.A	245
World	255	818	1,803	2,276

Source: Based on Ref. [3, 4, 13, 14].

respectively hold only 6% and 22% of the proven world reserves of fossil fuels. The per capita availability of fossil fuel reserves in the same two groups of countries is only 1/16th and 1/4th of that in the developed countries. Contrary to the general belief, even the fossil fuel reserves of high-income oil exporting countries are also limited, amounting to only 8% of the world total reserves. The situation of the developing countries with respect to per capita availability of uranium reserves and hydro potential is likewise much worse than that of the developed countries.

It may be pointed out that a number of oil exporting developing countries are now depleting their oil reserves at a very high rate. If such high rates of production are continued some of them (e.g. Bahrain, Ecuador, Egypt, Gabon, Indonesia, Peru, Qatar) will nearly exhaust their known oil reserves within a matter of the next 20 years, with some of them even becoming net oil importers.

2.3. *Imports*

It is worth noting that the developing countries as a whole are net exporters of energy, with their annual production of 3600 million TCE in 1980 (oil: 2560 million TCE, natural gas: 210 million TCE, coal: 650 million TCE, primary electricity: 180 million TCE) being almost twice as large as their own domestic consumption for the same year (oil: 900 million TCE, natural gas: 175 million TCE, coal: 665 million TCE, primary electricity: 180 million TCE). About half of total fossil fuels, in particular two-thirds of oil, produced in these countries during 1980 was exported to developed countries, meeting some 25% of their total fossil fuel requirements and 75% of those of liquid fuel in the market economy developed countries. However, only 28 out of the 130 odd developing countries are net exporters of energy (26 being net exporters of oil), while the rest meet their requirements to a varying extent through import of fossil fuels, mainly in the form of crude oil and refined oil products. In fact imported oil is responsible for meeting over three-fourths of commercial energy demand in two-thirds (as many as 68) of the Oil Importing Developing Countries (OIDCs). In 1980 the net oil imports of OIDCs were 360 million TCE, equivalent to about 80% of their oil demand or 45% of their commercial energy consumption. Imported coal accounted for an additional 2% of the 1980 commercial energy consumption in OIDCs.

3. Financial Difficulties

The sharp increase in oil prices during the last one decade has given a serious blow to the economies of OIDCs by causing several-fold increase in their energy import bills, leading to large current account deficits (see Figure 1), heavy borrowing from international sources — frequently at high interest rates — high debt service ratios and acute shortage of investment capital for financing the much needed socio-economic and domestic energy resource development programmes. A number of these countries, which were spending 5-10% of their export earnings on import of oil during the 1960s and early 70s are now forced to divert more than 50% of such earnings to pay for their oil imports. For some countries, e.g. Panama, Turkey, Yemen Arab Republic, the cost of oil imports even exceeds their earnings from merchandise exports. As estimated by the World Bank [5], the net fuel import bill of OIDCs in 1980 was $ 74

DEBT OF OIDC VERSUS OIL PRICES

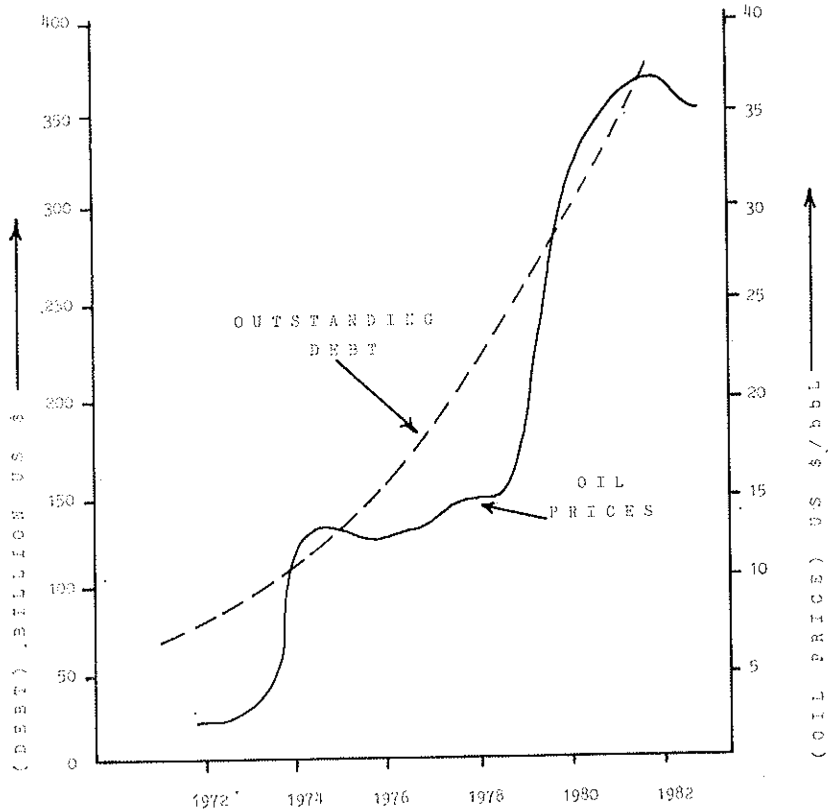


FIG. 1

billion equivalent to 5.3% of their combined gross domestic product (GDP), compared to 2.8% of GDP in 1978 and less than 1% of GDP in early 1970s. The same study projected that the bill will rise further to 6.2% of GDP by 1990. The net fuel imports of OIDCs in 1980 corresponded to 27% of their total merchandise imports and 36% of their total merchandise exports in that year.

The irony is that most of the OIDCs are exporters of primary commodities and the price index of non-oil commodities has since 1973 been decreasing not only with respect to index of petroleum prices but also relative to that of prices of manufactures imported by the developing countries. It decreased (as estimated by the World Bank [5] for 33 non-petroleum commodities) by 85% during 1972-82 relative to petroleum prices (see also Table 4) and by 43% between 1974 and 1982 relative to prices of manufactures imported by developing countries. The oil importing developing countries are under a double squeeze: they have to pay more not only for oil imports but also for the manufactured goods imported mainly from the developed countries, while the worth of their own exports is decreasing. Thus during 1970-80 in spite of more than 80% increase in the volume of non-fuel primary exports by the groups of low-income and middle-income OIDCs, each, the net purchasing power of such exports increased merely by about 15% in the case of the former group and hardly 30% in the case of the latter [5]. Due to worldwide slowing down of economic growth since 1980 and consequent reduction in international trade, the exports of non-fuel primary products and of manufactures from developing countries have grown (in volume) hardly, at annual rates of 0.6% and 4% respectively during 1980-82. This has further cut down the purchasing power of merchandise exports by OIDCs, more than half of which consist of non-fuel primary commodities in the case of low-income OIDCs and more than 35% in the case of middle-income oil importers.

The decrease in purchasing power of exports by OIDCs coupled with their increasing requirements of imports of both fuel and manufactured

TABLE 4 - *Erosion of purchasing power of primary commodities for oil* (1975-1984).

Commodity	Tons of Commodity Needed for Purchase of 1000 Barrels of Oil	
	1975	Jan. 1984
Copper	8.7	21.1
Lead	26.0	73.2
Tin	1.6	2.4
Coffee	3.5	9.5
Cotton	8.4	17.4
Sugar	23.9	189.4
Maize	94.3	246.3

Source: Based on Ref. [15].

goods, necessary for supporting the socio-economic development activities, have resulted in increasing their current account deficits in alarming proportions. The current account deficit of these countries increased from 9 billion US dollars in 1970 to $ 72 billion in 1980 and $ 80 billion in 1981 but is estimated [5] to decrease to $ 69 billion in 1982, due partly to recent reduction in oil prices and partly to impact of conservation measures following the second oil price hike during 1979-80. Since the Official Development Assistance (ODA) available to OIDCs can hardly cope with a quarter to one-third of their current account deficit, the OIDCs have by 1982 accumulated about $ 400 billion of official and private debts and are paying 23% of their export earnings towards debt service alone.

The middle-income oil exporters are also faced with financial difficulties. Their gross domestic product has grown during the last two years at about 1.7% per annum — only slightly better than the 1.1% growth rate for middle-income oil importers for the corresponding period. In order to finance their industrial investment programmes leading to higher economic growth and gradual independence from heavy reliance on income from their diminishing oil reserves, these countries have also been borrowing heavily from international sources on the strength of their present petroleum reserves. Their current account deficit, outstanding debt and debt service ratio in 1982 were respectively about $ 50 billion, $ 150 billion and 19% of export earnings.

Table 5 summarizes the overall current account deficit, outstanding debt, debt servicing, interest payment and ODA position of the developing countries (excluding the eight high-income oil exporters) in 1982 and compares it with that in 1970. It is seen that there is a deterioration all around except in the case of ODA, which has also remained stagnant at a level of 1% of the GNP of the recipients.

The financial problems of the developing countries (excluding high-income oil exporters) are due essentially to the following reasons:

i) Decreasing prices of non-petroleum primary commodities relative to prices of oil and those of manufactures imported by developing countries. This trend has continued in spite of efforts by UNCTAD, GATT and the Group of 77 to rationalise the prices of non-petroleum primary commodities.

ii) Undue barriers such as import restrictions, quota systems, heavy import duties etc., imposed by the developed countries on import of manufactured and semiprocessed goods from the developing countries.

TABLE 5 - *Deterioration in financial status of low- and middle-income developing countries between 1970 and 1982.*

	1970	1982
Current Account Deficit (U.S. $)	12.0	118.2
O.D.A.* (U.S. $)	4.7	23.9
Debt Outstanding (U.S. $)	69.4	548.0
Interest Payments on Loans (U.S. $)	2.7	49.5
Current Account Deficit as % of GNP	2.3	5.0
Current Account Deficit as % of Exports	17.3	22.0
O.D.A.* as % of GNP	0.9	1.0
Debt Outstanding as % of GNP	13.3	23.2
Debt Service as % of GNP	1.8	4.7
Debt Service as % of Exports	13.5	20.7
Interest Payments as % of GNP	0.5	2.1

* Net Official Development Assistance defined as net disbursements of concessional official loans plus net official transfers.

Source: Based on Ref. [5].

Again, efforts made by relevant U.N. bodies and developing countries themselves to seek removal/relaxation of these barriers have not so far found much success.

iii) Small size of ODA, that is loans and grants made at concessional financial terms by the Development Assistance Committee (DAC) of OECD, members of OPEC, and nonmarket developed countries. Although we are now approaching the midway mark of the 3rd UN Development Decade, the ODA contribution of a number of DCA countries is well below the bench mark (0.7% of GNP of the donor country) set by the UN for the 2nd UN Development Decade. In fact the overall average of ODA from the DAC countries has since 1970 remained close to half of the benchmark level. The OPEC countries, as a whole, have been relatively more generous; their contribution as a fraction of their combined GNP, although reducing since 1979, has still remained at or above 1.5% of GNP throughout since 1975. The contribution of nonmarket developed countries, on the other hand, has been even smaller than that of DAC countries.

iv) The very limited availability of loans from official sources necessitating increased borrowing from private sources at relatively much higher interest rates. The share of private loans in outstanding debt of developing countries increased from one-half in 1970 to two-thirds in 1980 and consequently the average effective interest rate on total developing country debt increased from 6.3 percent in 1970 to 8.9 percent in 1980. The London Inter Bank Offer Rate (LIBOR) for six-month $ deposits, which determines interest payments on the bulk of private bank loans, averaged 16.6 percent in 1981 and 13.5 percent in 1982 [5].

v) Difficulty in obtaining long-term loans (official as well as private) necessitating increased short-term borrowing or running down of reserves. Increasing dependence on short-term loans makes developing countries subject to rising interest rates and vulnerable to sudden withdrawal of support by commercial banks.

vi) Increasing difficulty of oil importing developing countries, particularly low-income countries, in obtaining private loans due to their conceived doubtful creditworthiness. The low-income countries have had to rely on ODA for more than 75% of their external capital throughout the 1970s.

All these financial difficulties of the developing countries have been affecting their energy sector development programmes in the past and are likely to continue doing so, perhaps much more severely, in the coming decades. The developing countries, both oil importing and middle-income oil exporting, need to make large investments in the energy sector — equivalent to 4-6% of GNP as against 2-3% now. The former need to do so in order to reduce their energy import dependence, and the latter to extend their dwindling energy resources and diversify their domestic energy supply system with a view to (i) ensure adequate supply of energy for increasing domestic requirements in the coming decades, (ii) expanding production for exports, both for boosting the supply of revenues for their much needed socio-economic development programmes and for continuation of their contribution to meeting the energy deficits in OIDCs and energy resource-deficient developed countries.

The developing countries have faced considerable difficulties in financing their energy investments, which acquired particular importance in the wake of oil price increases of 1973-74. The total amount of publicly guaranteed external borrowing (both official and private) for energy investments in developing countries in 1982 was, in terms of

1982 US dollars, $ 10 billion in 1975, $ 16 billion in 1980 and is estimated to be less than $ 25 billion in 1982 [3]. The share of private loans was about 75% during the period 1975-80. Even in the case of borrowing for the energy sector, the low-income countries have to be essentially content with multilateral and concessional bilateral loans, which have contributed about 80% to their external energy borrowing between 1975 and 1980 as against 22% and 17% for middle-income oil importers and middle-income oil exporters, respectively, and 25% for developing countries as a whole.

The external loans in 1982 (estimated at $ 25 billion), meant specifically for energy sector development in the developing countries correspond to about 30% of their total borrowing and 1.0% of their GNP for the year. The external energy sector loans to OIDCs during the last three years were hardly sufficient even to offset 15-20% of their oil import bill. Thus the external flows have so far been extremely inadequate to help the developing countries overcome their investment difficulties in the energy sector.

4. Prospects for Energy Demand and Supply

4.1. *Growth of Demand*

The developing countries, in general, are now passing through an energy intensive phase of socio-economic development, a phase in which they have to mechanise agriculture, establish industrial infrastructure, augment transportation and other service facilities, and provide electricity and other environmentally cogent fuels at adequate levels to their rapidly growing and increasingly urbanising population. The present day developed countries passed through this phase at a time when energy was cheap and abundantly available with prices of fossil fuels falling in real terms. But now that the developing countries are striving to climb on the development ladder, energy is becoming a scarce and increasingly expensive commodity. Yet energy being an essential input for practically all socio-economic development activities, its demand in the developing countries will continue to grow quite significantly in the foreseeable future, in spite of price-induced conservation measures, and restructuring of the economy and life styles, if a reasonable pace of economic development is to be maintained for countries of the Third World.

Until early 1970 the demand of commercial energy in the developing countries was growing at about 7% per annum as compared to 5% in the developed countries. Following the oil price hikes of 1973-74 the growth rates were slowed down in all but a few oil-rich countries due to the ensuing economic recession and conservation measures adopted by various countries. The average annual growth rates of commercial energy consumption during 1970-80 were: Developed countries: 2.4%; Developing countries: 6.1%; World: 3.0%. The overall income elasticity of energy demand during this period was 0.73 for the developed countries and 1.13 for the developing countries.

The future requirements of energy in both the developed and developing countries would depend upon their economic growth as well as the effectiveness of conservation measures that are adopted in the wake of rising costs of energy. Estimates made by international agencies [1-3] indicate that the average income elasticity of commercial energy demand in the next two decades or so will be in the range 0.5-0.7 for the developed countries and 0.9-1.1 for the developing countries, with prices of oil increasing in real terms at 0-1.5% per annum. Taking median values of these elasticity coefficients and assuming, in general agreement with the above studies, average annual GNP growth rates of 3.5% and 5% per annum, respectively, for developed and developing countries over the period 1980-2000, the demand for commercial energy will increase by the year 2000 to:

Developed Countries	11.0 billion TCE
Developing Countries	5.1 billion TCE
World	16.1 billion TCE

The share of developing countries in global demand will thus increase from 21% in 1980 to 32% in the year 2000. About 45% of the global increase in commercial energy consumption by the year 2000 will thus take place in the developing countries. The developing country demand in 1980 was distributed among different groups as:

Low-income oil importers	10%
Low-income oil exporter (China, only)	33%
Middle-income oil importers	33%
Middle-income oil exporters	20%
High-income oil exporters	4%

Only minor changes in this distribution are to be expected over the next 20 year period.

Two other aspects deserve a mention here. First, in the light of the past experience all over the world, the demand for electricity as end-use energy is expected to grow in both the developed and developing countries, much faster than that for fossil fuels used as such. Assuming then, in line with recent IIASA and World Bank studies [1, 3], the income elasticity hydropower generation (e.g. biogas, charcoal from plantations and harvesting of natural forests, alcohol production from biomass, solar energy, geo-thermal energy etc.) will be able to play only a minor role in the foreseeable future. The prospects of energy supply in the developing countries from these various options are briefly discussed below.

4.2.1. *Fossil Fuels*

The energy resources of fossil fuels are very unevenly distributed among the developing countries, as may be seen from Table 3. The high-income oil exporters (8 countries) are richly endowed with petroleum resources and are not likely to have any problems in meeting their domestic requirements of energy in the coming decades. In fact most of these countries will, in all probability, continue to export for the next several decades their surplus production of oil, and possibly natural gas (through pipelines and as LNG) to meet the energy deficits in other developing countries and the industrialized world. It is, however, in their interest to increase the share of natural gas in their domestic energy consumption, particularly by utilising gas which is still being flared due to lack of collection and distribution facilities. The use of gas in place of oil, wherever possible, will release some additional supplies of oil which are likely to fetch higher revenues through exports than the export of equivalent quantities of natural gas (whether as gas or liquid).

The middle-income oil exporting developing countries (17 in all) were able to export more than three quarters of their oil production in 1980 and, as a group, are likely to continue their oil exporter status over the next two or three decades. However, 11 of these countries have at present oil reserves-to-production ratio [3] of less than 30:1, with 4 of them having this ratio even less than 15:1. It is mainly because of a few countries (e.g. Iran, Iraq, Mexico) with large reserves and relatively low depletion rates that the overall oil reserves-to-production ratio for these countries was 43:1 in 1980. Unless sufficient effort is made on exploration of new oil in these countries, their oil export potential may become stagnant or even decline in the coming decades. Countries such as Egypt, Gabon, Indonesia, Peru and Trinidad and Tobago are particularly vulnerable to becoming oil importers for want of adequate effort on exploration and development of new oil fields and secondary oil recovery in the near future. The natural gas potential in the middle-income oil exporters is still very much under-utilised. Their present reserves-to-production ratio for gas is close to 300:1 while the share of natural gas in their commercial energy consumption in 1980 was only 22%. These countries need to invest more in the development of natural gas both for domestic consumption and export purposes. None of the middle-income oil exporting countries has significant reserves of coal; their total coal reserves are less than 4 billion TCE with about one third of these in Indonesia. Indonesia, which is particularly experiencing rapid depletion of its oil reserves and does not have large gas reserves (total gas reserves: 800 million TCE), may find it useful to develop its coal fields for the domestic market.

China is the only oil exporting country among the low-income countries. Its present oil production exceeds the country's domestic consumption by only 20%. With present oil reserves-to-production ratio of about 25:1 it can hardly be considered as a potential exporter of oil in the coming decades. Its natural gas reserves are inadequate to allow significant increase in the share of gas in domestic energy consumption, which in 1980 stood at about 3%. The bulk of commercial energy consumption (about 72% in 1980) in China is based on coal. The country is one of the three giant holders of global coal reserves. Its proven coal reserves are about 100 billion TCE and the present production (all meant for domestic consumption) stands at a level of 450 million TCE. China would need to further develop its coal resources both for domestic consumption and export.

Among the oil importing developing countries, (more than 100 in number) several are believed to have reasonable prospects for economic petroleum reserves. However, the exploration activity in these countries has been extremely low due to shortage of capital and necessary technical know-how as well as lack of interest by International Oil Companies (IOCs). The total number of exploratory wells drilled per year in these countries has stayed at a level of 3-4% of the world total [3] throughout the 1970s. Whatever little activity there exists is also concentrated in a few oil producing countries, most notably Argentina, Brazil and India. With their present oil reserves-to-production ratio being close to 15:1, production can not be increased significantly in the OIDCs unless sizable new reserves are discovered. Their natural gas reserves are, however, still under-utilised due to lack of both capital and interest by IOCs. The share of natural gas in overall commercial energy consumption of these countries is still less than 4% while the gas reserves-to-production ratio is close to 80:1.

Large coal reserves (about 34 billion TCE) exist in India with sizable deposits (3-8 billion TCE) also existing in Brazil, Colombia and Yugoslavia. Coal had a significant share in commercial energy consumption in 1980 in India (55%), Republic of Korea (31%), Yugoslavia (38%) and Turkey (21%), with its share in the overall commercial energy consumption of the rest of OIDCs being only 14%. The OIDCs with large coal reserves are, in general, finding it difficult to enhance production due to capital shortage, inadequacy of transportation facilities and lack of interest by users due to inconvenience of its use and insufficient economic margin over alternative fuels.

There is a bleak future for those OIDCs with little or uneconomic domestic resources of coal and natural gas. They will not only have to continue importing oil for transportation and similar other specific uses but will also have to import both oil and coal for meeting the bulk of their requirements of process heat. At present their import of coal is only 1/20th that of oil and more than 80% of it is due to just three countries: Brazil, Republic of Korea and Yugoslavia. Substituting imported coal for imported oil will not be an easy transition for OIDCs; it will call for heavy investments in establishing/extending the necessary infrastructure (port handling, storage, internal transportation, etc.). These countries therefore need, more than anyone else, to develop non-fossil energy supply alternatives in parallel with intensification of their effort on fossil fuel exploration and development.

4.2.2. *Electric Power*

Electric power is a key component of the energy supply system in all countries. It accounted for about 25% of the commercial energy consumption in developing countries in 1980. The total amount of electricity generated in these countries in 1980 was about 1200 billion KWH supplied by 306,000 MW installed power generation capacity comprising

32% based on oil, 8% on gas, 21% on coal, 38% on hydro, 0.6% on nuclear and 0.2% on geothermal energy. The distribution of installed capacity among different groups of developing countries is shown in Table 6. Also shown in the Table is the fraction of total technically exploitable hydroelectric potential in each group that had been developed by 1980.

As discussed in section 4.1, the income elasticity of electricity demand in the developing countries over the next two decades or so is expected to be around 1.5. Then, for a medium pace of 5 percent per annum average overall economic growth in these countries, their requirements of electricity generation capacity will increase by factors of 2.1 and 4.3 during the 1980s and 90s respectively, necessitating total installed power generation capacity of about 650×10^3 MW in 1990 and 1300×10^3 MW in the year 2000. The rest of this section covers the energy supply outlook for electricity generation in the developing countries. The non-fossil fuel options will be discussed first.

Hydro: Hydro is a particularly attractive source for power generation

TABLE 6 - *Installed power generation capacity and fraction of hydro potential exploited till 1980 in developing countries.*

Country Group	Installed Power Capacity: Total 10^3 MW	Thermal (%)	Hydro (%)	Nuclear (%)	G. Thermal (%)	Fraction of Hydro Potential Exploited (%)
Low-income						
Oil Importers	46	54	44	2.2	—	7
Oil Exporters	66	69	31	—	—	5
Middle-income						
Oil Importers	130	51	48	0.7	0.4	3
Oil Exporters	54	69	31	—	0.3	26
High-income						
Oil Exporters	9	100	—	—	—	—
All Developing Countries	305	60	39	0.6	0.2	8

Source: Based on Ref. [3, 4, 13].

since its fuel cost is zero and operation and maintenance cost is minimal. However, this advantage is mitigated in terms of overall cost of electricity generation if the capital cost gets too high. At present international prices of coal and oil, hydropower's economic limit of capital cost is roughly $ 2000 to $ 3000 per KW of installed capacity [3]. As shown in Table 6, so far only about 8% of the technically exploitable hydropower potential in the developing countries has been put to use. There are considerable difficulties both in further expansion of hydropower and in continuing heavy reliance on this source. First, the most attractive sites have already been developed and the cost of construction of new dams is increasing with increasing complexity of dams at less favourable sites. Second, in most cases new sites are far away from demand centers, thereby necessitating huge additional investment in transmission lines and, still having their generated electricity subject to substantial transmission losses. Third, the water levels in storage dams undergo large seasonal variation, which markedly reduces the generation capability in low reservoir level months. And fourth, large dams in the developing countries are often multipurpose (power generation, supply of irrigation water, flood control) — that is how the heavy investment gets economically justified. In general, the water release pattern from such dams in low reservoir level periods is dictated by the irrigation requirements rather than by the needs of power generation. These last two factors, for example in the case of Pakistan, are responsible for reducing the generation capability of the hydro system in April to less than half of that in August.

In view of the above factors, rapid development of the technically exploitable hydropower potential in the developing countries can not be expected in the coming decades. The World Bank has recently estimated [3] that by 1995 the installed hydropower capacity in these countries will be less than 15% of the technical potential. Thus hydro may be expected at best to contribute about 300×10^3 MW generation capacity by the year 2000 to the electric supply system of the developing countries, thereby meeting some 23% of their envisaged requirements.

Nuclear: Nuclear power is now a technologically well established and economically proven option which holds considerable promise for providing electricity in an economical way, independent of fossil fuel prices, to both developed and developing countries. Already by the end of 1982 there were 297 nuclear power reactors with a total capacity of 173,000 MW, operating in 25 countries and meeting about 11% of the global requirements of electricity [6]. The share of nuclear in electricity generation in seven developed countries was more than 25% (e.g. Finland: 42.4%, France: 38.7%, Sweden: 38.6%) and in some it is expected to exceed 50% by 1990 (e.g. France: 70%, Belgium: more than 50%). The nuclear power now has more than 3000 reactor-years of operating experience with a safety record better than that of any other large industry. In spite of some setbacks in a few large countries, due mainly to economic and political reasons, nuclear power is expected to continue growing and would be able to supply [7] about 18% of global electricity in 1990 (22-23% in the developed countries) and 21-26% in the year 2000 (28-35% in the developed countries). In addition to the 25 countries with operating power reactors in 1982 there were 12 others with power reactors under construction or in advanced planning stages [8].

Despite the increasing role of nuclear power worldwide, and particularly in energy resource-poor developed countries, the developing countries have been rather slow in making use of this technology. By the end of 1982 only 6 developing countries had operating power reactors with total capacity of about 3700 MW and contributing 1.6% to electricity generation of developing countries. On the basis of reactors under construction or in advanced planning stages it is expected that 3 additional developing countries will have operating power reactors by 1990 and perhaps 7 more in the years shortly thereafter. Table 7 lists the developing countries with operating, under construction and planned power reactors (as of December, 1982), the number of reactors and their capacity. Based on the recent IAEA projections it is to be expected that the nuclear generation capacity in the developing countries will increase by the year 2000 to 30,000-75,000 MW and contribute 5-8% to their total electricity generation in that year [7].

Various international studies have shown that nuclear power has economic advantage over power generation based on coal and oil fired plants except perhaps in countries having large reserves of good quality coal but with low production and transportation costs. Table 8 based on a recent OECD study [2] compares the overall cost economics of power generation based on nuclear and coal/oil fired plants in the U.S., Western Europe and Japan. It is seen that, in spite of the per KW capital cost of nuclear plants being 1.5 and 2 times as high as that of coal and oil fired plants, respectively, nuclear generated electricity is considerably cheaper in all cases except the U.S., where coal-fired power generation has marginal economic advantage over nuclear. A World Bank study [4] also concluded that both large and medium sized nuclear plants

TABLE 7 - *Status of nuclear power reactors in developing countries, as of December 1982.*

	Operating Reactors		Reactors under Construction		Planned Reactors	
	Number	Capacity (MW)	Number	Capacity (MW)	Number	Capacity (MW)
1. Argentina	1	335	2	1,292	3	1,800
2. Brazil	1	626	2	2,490	6	7,470
3. China	—	—	—	—	?	?
4. Cuba	—	—	1	408	1	408
5. Egypt	—	—	—	—	8	8,400
6. India	4	809	4	880	6	1,320
7. Iraq	—	—	—	—	1	600
8. Israel	—	—	—	—	1	900
9. Korea, Rep.	2	1,193	7	6,227		3,456
10. Libya	—	—	—	—	2	816
11. Mexico	—	—	2	1,308	—	—
12. Pakistan	1	125	—	—	1	937
13. Philippines	—	—	1	620	—	—
14. Thailand	—	—	—	—	1	900
15. Turkey	—	—	—	—	1	1,000
16. Yugoslavia	1	632	—	—	1	1,000
Total	10	3,720	19	13,225	36	29,007

Source: Based on Ref. [6, 8].

would have significantly lower electricity generation costs than oil fired plants of comparable size in the OIDCs, but the margin would be relatively small compared to coal fired plants. A similar conclusion has been reached in a recent analysis by IAEA for plants of 600 MW or more [6]. As seen in Table 8, the fuel cost of a nuclear plant is a small component (25%) of the generation cost in the case of a nuclear plant but accounts for 40-80% of generation cost in the case of fossil fuel fired plants. As a result the higher capital investment in the nuclear plant will be offset by its lower fuelling cost in the first few years of plant operation and its cumulative lifetime discounted cost will turn out to be much lower than that of an equivalent fossil fuel fired plant.

At present indigenous nuclear power plant construction capability

TABLE 8 - *Indicative cost estimates for electricity generation by fuel* (in 1981 US $, capacity factor: 65%).

	Oil 2×600 MW Low sulphur	Oil 2×600 MW High sulphur with FGD*	Nuclear PWR 2×1100 MW	Coal with FGD* 2×600 MW U.S.	Coal with FGD* 2×600 MW Europe	Coal with FGD* 2×600 MW Japan
Capital Investment ($/KW)	577	692	1331	920	920	956
Fuel Cost ($/TCE)	$ 33/bbl (157)	$ 27/bbl (129)	(27)	$ 40/t (40)	$ 65/t (67)	$ 65/t (67)
Generation Cost (Mills/KWH)	67.9	64.7	39.0	38.2	48.2	48.9
Capital Cost	15.9%	19.9%	63.8%	44.7%	35.5%	36.4%
Operating Cost	3.7%	6.5%	10.7%	13.4%	10.6%	12.4%
Fuel Cost	80.4%	73.6%	25.5%	41.9%	53.9%	53.2%

* Flue Gas Desulphurization.

Source: Based on Ref. [2].

exists only in one developing country: India, which is building plants of about 220 MW capacity, but plans to build larger plants of 500 MW capacity in the near future. Other developing countries have been importing nuclear plants from the developed countries which now are being supplied in unit capacities of 440 MW (USSR design) and 600-1400 MW (designed by USSR, Western Europe and North American countries). Small units in the range of 100-200 MW (e.g. KANUPP in Pakistan and TARAPUR in India) were supplied by the developed countries in the 1960s and early 70s but those designs are not commercially available any more. In fact the current nuclear power industry in the developed countries is geared to construction of only large sized plants which fit well into their own comparatively much larger grids.

Although many developing countries are interested in making use of nuclear power to diversify their power generating system and reduce fossil fuel consumption, they can not plan for it simply because the cost economics of small sized nuclear power plants, now being offered by some manufacturers, is extremely unfavourable and the larger more economical plants would not fit into their grids in the next decade or so.

If only smaller nuclear plants, 100-300 MW, can be made economically competitive and offered to developing countries, a very large number of them could benefit from this relatively abundant source of energy. On the basis of the criterion that the capacity of an individual unit should not be more than 10% of the total installed capacity in the national grid, by the year 2000 as many as 71 developing countries would be able to accommodate in their national grids (assuming that the grid is integrated in each country) nuclear units of 100 MW or more, 46 countries: 300 MW or more, 33 countries: 600 MW or more and 26 countries: 900 MW or more. Work is reported to be in progress in several developed countries (U.K., France, Japan, F.R.G., Sweden, Canada, U.S.S.R. and the U.S.) on the development of small and medium power reactors (SMPRs) intended for electricity and/or process heat generation [9]. The IAEA has also been taking some interest — although it does not seem to be adequate — in promoting development and information exchange on small plants [6]. There is a need that concerted effort be made to open up the vistas of nuclear power to developing countries with relatively small grids by making small and medium power reactors economically competitive.

Apart from grid size consideration and non-availability of economic SMPRs, there are also other major difficulties in the way of developing countries, preventing them from making use of nuclear power even when the above mentioned limitations do not apply. Some of these are financial, some related to infrastructure requirements and some due to lack of international co-operation. These will be discussed in Section 5.

Fossil Fuels: From the preceding discussion it follows that, as seen by energy analysts to-day, hydro and nuclear power are expected to contribute less than 25% and 10%, respectively, to the installed electricity generation capacity in the developing countries by the year 2000. The brunt of the load will, therefore, have to be borne by fossil fuels until after the turn of the century. In view of the growing scarcity of oil its share in thermal power generation is expected to decrease in almost all countries except perhaps those with capacity requirements of less than a few hundred MW. The likely sources of substitution are: domestic coal in countries with significant coal reserves, natural gas in countries where gas reserves are still very much under-utilised or gas is being flared for want of gathering/distribution facilities, and imported coal, mainly from developed countries, in those developing countries which are short of all fossil fuel resources. Again, this renewed dependency on import of yet another fossil fuel will hardly help solve the financial problems of the resource-deficient OIDCs or provide them with any degree of energy security. The real solution for them lies in rapid expansion of their domestic production capacity of fossil fuels through intensive exploration and development effort, together with use of nuclear power, hydro and other renewable sources of energy to the maximum feasible extent. All this calls for large capital investments, full mobilisation of domestic resources and, last but not least, a high degree of international co-operation.

5. International Co-operation

5.1. *Energy Investments*

The development activities in the energy sector are becoming increasingly more expensive. In the low- and middle-income developing countries the share of energy investments in GDP has already increased from a level of 1-2% in the early 1970s to 2-3% now, and is likely to increase further to 4-6% over the next two decades [1, 3]. According to the World Bank estimates [3] these countries will need to spend on energy investments over the next 10 years an average of $ 130 billion a year (in 1982 prices) of which about half ($ 64 billion a year) will have to be in foreign exchange. Still the energy import dependence of OIDCs would not be eliminated — with the aforementioned investments, if they were to take place, it is projected to decrease modestly from about 43% in 1980 to 32% in 1995, while the energy export capability of the low- and middle-income oil exporters is projected to decrease from about 48% to 44% of their production over the same period. The particularly difficult situation will be that of OIDCs, which will not only have to find large investments for energy sector development but will also have to finance their energy imports at a level of 5-6% of their GDP.

As discussed in Section 3 the low- and middle-income developing countries, in general, and the oil importing developing countries, in particular, are facing serious financial difficulties with their current account deficits and debt service charges, each, running at a level of about 5% of GNP, the Official Development Assistance from more developed and high-income developing countries stagnating at an overall level of 1% of the GNP of the recipients. The interest rates of private loans are rising upwards and the availability of such loans is becoming increasingly difficult. The present level of external energy sector loans available to low- and middle-income developing countries is extremely inadequate to meet their needs; it can hardly cover 15-20% of their energy investment requirements. In view of the fact that future development prospects of OIDCs are heavily dependent on their ability to rapidly increase domestic energy production and cut down import of energy, and those of the low- and middle-income energy exporting countries on expanding their energy export revenues while maintaining a high reserves-to-production ratio and a stable price of oil at a level conducive to world economy, it is necessary that:

i) The level of official loans (both on concessional and non-concessional terms) be increased, in general, and that for the energy sector, in particular. The donor countries now contributing below the 0.7% of GNP level recommended by the UN, should reach this target without delay, while those with higher contributions should maintain their higher level. The IDA commitments to low- and lower middle-income countries have been decreasing, even in terms of current dollars, for the last three years; they decreased from \$ 3.8 billion in 1980 to \$ 3.5 billion in 1981 and \$ 2.7 billion in 1982 [10]. This trend should not only be reversed but also the IDA commitments increased substantially in real terms.

ii) Loans from private banks and financial institutions for energy sector development, should be increased and terms made easier for the developing countries. International financial agencies should encourage such lending to low-income or less credit-worthy countries by providing the necessary guarantees. The present practice of co-financing by the World Bank and other similar international organisations should be considerably strengthened, particularly for the energy projects, in order to attract much more external capital.

iii) International Finance Corporation, an affiliate of the World Bank, should substantially increase its equity participation programme in energy sector investments in the developing countries to attract much more direct private investment by international energy industry, particularly international oil companies. Other international organisations should also likewise launch equity investment programmes in the developing countries.

Unless these steps are taken by the international agencies and the developed/high-income countries, there is little hope that the low- and middle-income developing countries will be able to invest in the development of the energy sector to the required level. Consequently their problems will get much worse and prospects of their economic growth considerably reduced. The reduced level of economic development in these countries will in turn result in a loss of export market by the developed countries and also possibly by the high-income oil exporters, thereby adversely affecting the world economy as a whole. There is also a serious danger that without accelerated development of the energy sector, which is closely linked to economic growth, the debt-ridden developing countries, particularly OIDCs, will be forced to ask for debt rescheduling or even be compelled to default. This would seriously jolt the current banking system, which has to be protected for healthy international trade and commerce.

5.2. *Transfer of Technology*

The developing countries, as the terminology itself indicates, are short of economic and technological resources necessary for the development process. Not only are their skills, know-how and industrial infrastructure very limited, they are also not in a position to develop them fast enough on their own. And without recourse to modern technology they can not hope to overcome their backwardness in a reasonable time. What is, therefore, needed is a new era of international co-operation in which the human, material and technological resources of both the developed and developing countries are shared for the benefit of mankind as a whole.

There is a continuing large transfer of non-renewable and limited resources of raw materials, particularly oil, taking place from the developing to the developed countries. It is rather unfortunate that this transfer of raw material resources, which plays a key role in the economic growth and affluence of the developed countries, is not matched by a commensurate transfer of renewable financial and technological resources to the Third World. The developing countries need access to advanced technology not merely for solving some of their present-day problems but equally for extending and prolonging their production capability of raw materials, which will be required in increasing quantities both by themselves and by the developed countries in the years to come.

In the energy field there are many areas where the developing countries are in need of access to modern technology and improvement in their know-how and technological skills. Some examples are: systematic surveys of petroleum, coal, uranium and hydropower resources; drilling for petroleum through high temperature and high pressure reservoirs and in off-shore areas; enhanced recovery of oil and gas; mining of coal, both surface and underground, by modern, safe, economic and more efficient techniques; construction of large dams; use of nuclear power and development of the associated fuel cycle capability etc. Numerous examples can be given in almost every area to show that developing countries are having a hard time in getting access to modern technology or to relevant skills. But the most glaring example is that of nuclear power and it is this aspect that will be discussed here.

The importance of nuclear power as a safe, reliable and economic source of electricity generation that provides considerable relief from dependence on rapidly depleting fossil fuel resources, is now well recognised. Some of these aspects have been discussed in Section 4.2.2. However, access to this technology is now becoming increasingly difficult for the developing countries, in spite of the fact that they need it more than anyone else, to ensure provision of adequate electricity at reasonable cost for their socio-economic developmental activities and to diversify their energy supply system. These difficulties have arisen gradually over the last two decades due to linkage of nuclear power with nuclear weapon proliferation perceived by some nuclear weapon states, but have become particularly serious since 1974 following the underground nuclear explosion by India.

In fact during, the 1950s and early 1960s use of nuclear power was being preached as an inexhaustible cheap source of electricity to the developing countries by the U.S. and other developed countries, who were rapidly developing their own power reactor programmes. The "Atom for Peace" plan launched by the United States in the mid-1950s went a long way in initiating peaceful nuclear technology programmes in several developed and developing countries. Until the early 1960s nuclear power and nuclear weapon development were, by and large, considered as independent. However, following the first nuclear weapon explosion in 1964 by China (which, incidentally, has not any operating power reactor as yet), the two super powers worked together to formulate the Non-Proliferation Treaty (NPT), which came into effect in 1970. It may be pointed out here that the IAEA was not associated with the formulation of this treaty, nor were the recommendations of a conference of Non-Nuclear Weapon States (NNWS), organised by the United Nations in 1968, incorporated in the NPT draft text to cover the specific needs of NNWS, particularly those for peaceful applications of nuclear technology and their security problems.

The NPT was supposed to be based on a "quid pro quo" consisting of a balance between certain obligations and privileges. The NNWS signatories to the NPT agreed to give up their nuclear weapon option in return for a promised fullest possible exchange of equipment, materials and scientific and technological information for the peaceful uses of nuclear energy, including the use of peaceful applications of nuclear explosions under strict international control. The Nuclear Weapon States (NWS), for their part, assumed the role of nuclear guardians and in return undertook "to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a treaty on general and complete disarmament under strict and effective international control" (Article VI). The de facto position is that the NPT has been virtually rewritten and is being interpreted to suit the NWS which use the Treaty to put additional restrictions on the NNWS regarding acquisition of so-called sensitive technologies including enrichment and reprocessing in complete contradiction to Article IV. The transfer of technology has been reserved only for a few major developed countries, and, as a result, a special group of countries has emerged that is considered entitled to receive the so-called sensitive nuclear technology; the rest are not "trusted" in spite of their unquestionable commitments to the NPT. At the same time NWS have not taken any steps toward actual reduction in their nuclear stockpiles. Instead, there has been an unabated race towards increasing the quantity and quality of the nuclear weapons, which has led to the development of new weapon systems with ever greater destructive power, strike accuracy and deployment flexibility.

Following the Indian underground explosion in 1974, the NWS, instead of analysing this event objectively and understanding its technical, strategic and political implications, chose to stress controls and denial of access to technology as the primary measure for stopping any further spread of nuclear weapons capability. This led to the creation of the London Suppliers Club, whose comprehensive guidelines effectively implied almost complete denial of nuclear technology to those outside the club. In order to help solve these problems, which particularly affect nuclear power development programmes in the developing countries, the

IAEA set up a Committee on Assurances of Supply and launched a study on the proliferation potential of various nuclear fuel cycle strategies, called the International Nuclear Fuel Cycle Evaluation (INFCE). The final communique of INFCE stated [11] "that nuclear energy is expected to increase its role in meeting the world's energy needs and can and should be widely available to that end; that effective measures can and should be taken to meet the specific needs of developing countries in the peaceful uses of nuclear energy; and that effective measures can and should be taken to minimize the danger of the proliferation of nuclear weapons without jeopardizing energy supplies or the developments of nuclear energy for peaceful purposes".

Even before the closing of INFCE, and thus before the prospective recipient countries could derive any statisfaction out of the conclusions of this unprecedented and comprehensive study, the U.S. adopted its Nuclear Non-Proliferation Act (NNPA) of 1978. The provisions of this Act, according to many observers [12], are actually contrary to the terms of reference of INFCE and also undermine the assurances given to the recipient countries under the NPT. It is, perhaps, the most restrictive legislation of its kind and has far-reaching international implications by enabling a country to make changes in international treaties and agreements. Similar practices of retroactive application of national legislation or policies have also been adopted by other supplier countries.

The nuclear power development programmes in several developing countries (e.g. Argentina, Brazil, India, Pakistan, Yugoslavia) have been adversely affected due to such restrictive policies and denial of nuclear technology by the developed countries. A number of other countries feel discouraged or have been dissuaded from turning to nuclear power for meeting their future electricity needs. All this is because proliferation, which is basically a political problem, is erroneously being linked with peaceful use of nuclear energy. It may be emphasized that denial of nuclear power technology to developing countries would not only make energy supply more expensive and difficult for the developing countries but would also increase the pressure on global resources of fossil fuels, particularly those of oil, thereby making the energy supply position increasingly difficult almost everywhere. The IAEA safeguards are basically sound and provide credible assurances. There have been no instances of non-compliance with Agreements or diversion from the facilities under the Agency safeguards. It would be extremely difficult, if not virtually impossible, for any country to divert significant quantities of fissile materials without timely detection, and if it attempts to do so, it cannot face the formidable adverse international public opinion and attendant serious consequences. It is imperative, therefore, that all countries work together in supporting the Agency in its dual role of promotion and regulation of nuclear power with equal vigour and emphasis.

International co-operation in transfer of energy technologies is of paramount importance for increasing the energy supply potential of the developing countries and, in turn, for ensuring increased supply of energy on a global basis. There is a large scope for such co-operation in respect of each and every source of energy, most notably in the case of nuclear power. The need for economical small and medium sized power reactors for developing countries was discussed earlier in this paper. Development of such power reactors should be pursued at an accelerated pace. At the same time the present obstacles in the way of transfer of peaceful nuclear technology should be removed by looking at the proliferation issue in a logical and rational manner. International co-operation in the transfer of other energy technologies needs, likewise, to be promoted with full vigour.

6. Conclusion

Assured supply of adequate energy at reasonable cost is crucial to the well-being and continued economic progress of both the developed and developing countries. Although the present level of energy consumption in the developing countries is small, they are now passing through an energy-intensive phase of development and will need increasingly large inputs of energy for implementing their socio-economic development programmes. Taken as a whole, their energy resource base is much weaker than that of the developed countries. A large majority of them are heavily dependent on imported energy, and are facing large current account deficits and have accumulated heavy debts due to increasing costs of energy imports. Most of the oil exporting developing countries are producing oil in excess of their needs, not because they have large resources but because that is the only way they can earn some revenues for financing their developmental needs. Still they are having serious current account deficit problems and have been forced to borrow heavily from private sources at high interest rates. If the present high rate of oil production is continued, a number of these countries will exhaust their oil reserves within a matter of the next 10 to 20 years and turn into net energy importers.

The developing countries as a whole are net exporters of petroleum and several other raw materials to the developed countries. In fact they are doing so even at the risk of depleting their own resources and facing serious shortages in the coming decades. However, this transfer of resources is not being matched by transfer of technology in the reverse direction. The advanced technology and technological know-how are denied to them sometimes under the guise of patent rights and sometimes on the pretext of sensitive technologies. This denial of technology, coupled with shortage of investment funds, is seriously hampering the development activities in most of the developing countries in almost all fields, particularly in the field of energy resources. The slowed down pace of economic development and increasing scarcity of energy supply in the developing countries will not only be harmful to them but will also adversely affect the developed countries through loss of market for their manufactures and reduced availability of energy to cover their own deficits. It is, therefore, in the interest of the developed countries to help boost economic development and energy supply in the developing countries through transfer of advanced technology and technological skills and by providing necessary funds for critical investments.

Among the various energy supply options, nuclear power stands out as an economic and inexhaustible source of electricity generation. The developing countries are facing serious difficulties in making full use of this source due to undue linkage of nuclear power with nuclear weapon proliferation. Various international studies have clearly established that there is no direct relationship between nuclear power development and proliferation, which is purely a political issue, and that nuclear power is essential for expanding energy supplies in both the developed and the developing countries. There is, therefore, an urgent need for the rethinking of all the important issues pertaining to nuclear power and non-proliferation. It should be realised that the problems of world security are indivisible and that no single nation or group of nations can enjoy security and prosperity at the expense of or without the co-operation of an overwhelming majority of world population.

International agencies such as the World Bank and the IAEA have a very important role to play in overcoming the financial and technological problems of the developing countries. Tbe relevant international organisations should seek to increase the availability of Official Development Assistance, private loans and external investment in the developing countries, particularly for their energy sector development. Some time ago the World Bank had proposed to create an affiliate to deal specifically with energy sector development issues in the developing countries, which has been deferred. It is felt that creation of such an energy affiliate by the World Bank and providing it with adequate resources could go a long way in solving the energy problems of the developing countries. The IAEA has been taking interest for some time in the promotion and development of small and medium power reactors. In view of the large potential market for such reactors in the developing countries, their development deserves a much increased emphasis and support by the Agency.

Finally, it should be appreciated by all that the developed and the developing countries, those with resources of one particular kind or the other and those with hardly any, have all one common destiny, the overall welfare of mankind. Without this there can not be global peace or global security. We have to share our resources, material, technological and human, for the common good of all.

Acknowledgement

The assistance of Dr. Arshad Muhammad Khan, Chief Scientific Officer of Pakistan Atomic Energy Commission, in the preparation of this paper is gratefully acknowledged.

REFERENCES

[1] International Institute for Applied Systems Analysis, « Energy in a Finite World », Report by Energy Systems Program Group, W. Häfele, ed. (Cambridge, Mass.: Ballinger, 1981).

[2] International Energy Agency, « World Energy Outlook », (Paris. OECD/IEA, 1982).

[3] « The Energy Transition in Developing Countries », Washington, D.C., World Bank, 1983.

[4] « Energy in Developing Countries », Washington, D.C., World Bank, 1980.

[5] « World Development Reports 1981, 1982, 1983 », Washington, D.C., World Bank, 1981, 1982, 1983.

[6] « Status and Trends of Nuclear Power Worldwide », Report by the Division of Nuclear Power (Vienna: International Atomic Energy Agency, September 1983).

[7] « Energy, Electricity and Nuclear Power Estimates for the period up to 2000 », IAEA Reference Data Series No. 1 (Vienna: International Atomic Energy Agency, September 1983).

[8] « Nuclear Power Reactors in the World », IAEA Reference Data Series No. 2 (Vienna: International Atomic Energy Agency, September 1983).

[9] J.R. Egan, « Small Reactors: Facts or Fancy? Conference on Nuclear-Electric Power in the Asia-Pacific Region », East-West Resource Systems Institute, Honolulu, Hawaii, January 1983.

[10] The World Bank, « IDA in Retrospect », (Oxford: Oxford University Press, 1982).

[11] « INFCE Summary Volume », p. 276 (Vienna: International Atomic Energy Agency, 1980).

[12] Bertrand Goldschmidt, « The Atomic Complex » (La Grange Park, Ill.: American Nuclear Society, 1982).

[13] « Yearbook of World Energy Statistics, 1980 », (New York: United Nations, 1981).

[14] « Uranium Resources, Production and Demand », A joint Report by the OECD Nuclear Energy Agency and the International Atomic Energy Agency (Paris: OECD, 1982).

[15] South (London), p. 79 (March, 1984).

[16] The Economist (London), p. 71 (14-20 April, 1984).

IAEA'S VIEWPOINT ON ENERGY IN DEVELOPING COUNTRIES — ROLE OF NUCLEAR POWER

H. J. LAUE
International Atomic Energy Agency
Vienna, Austria

On behalf of the Director General, Dr. Hans Blix, it is my great pleasure to express the IAEA's gratitude for the invitation to address this important workshop and to comment on the Agency's viewpoint on energy in developing countries and the role nuclear power plays and will play in the future.

As laid down in the Agency's statute, "The Agency shall seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world", and I shall start with two introductory remarks.

Firstly, atomic energy is generally taken to mean the process of and the applications of nuclear reactions. In the first instance, there is the nuclear fission for the production of heat and electricity in a nuclear power plant. However, for the majority of developing countries, nuclear power has not yet become a practical option. Most of the IAEA's activities, therefore, have consisted of assistance to developing countries on nuclear science techniques related to radioisotopes. There they are playing a valuable role and assist in treating diseases, eradicating pests, augmenting agricultural production, improving the quality of food, assessing and managing water resources and increasing the efficiency of industrial products. There is hardly any field of human endeavour to which nuclear science and the use of atomic energy in this broader sense does not have an application.

Secondly, we have to understand that nuclear power is not a panacea to solve the energy problem of the majority of developing countries. We must, therefore, distinguish between a minority of about a dozen of developing countries already using nuclear power to meet the energy requirements of the future and the majority of around 120 developing countries with very low energy and electricity consumption levels, either in total or per capita, which will not justify the use of nuclear power in the foreseeable future.

Having said this, I would like to briefly analyse the present and future energy, electricity and nuclear power situation in developing countries and the reasons which are limiting the nuclear power application in additional developing countries.

Such an analysis must be seen in the context of the key position which energy plays and will play for the economic and social development of any country. In spite of all necessary conservation measures, at least in industrialized countries, and the present world-wide economic crises and the corresponding slow-down in energy demand, the world is going to need more energy in the future because of two important elements:

(i) The predicted increase in the world population from the present 4,4 billions to around 6 billions at the end of this century and possibly 8 billions in the year 2020;

(ii) The improvement expected and needed in the standard of living in the less developed countries, which can only be assured if the present standard of living and industrial and economic activities in the developed countries will be maintained.

As shown in Fig. 1, the world-wide demand for primary energy during the period from 1981 to 2000 might increase by a factor of around 1,7 and in developing countries by a factor of around 2,25, whereas the consumption of energy per capita will only increase world-wide by a factor of 1,2 and in developing countries by a factor of 1,6. Consequently, energy will remain a basic requirement where the greatest difference exists between countries, as demonstrated in Fig. 2 with a comparison of energy consumption per capita in some selected countries.

We also have to realize that the consumption of electricity has been growing and will continue to grow more rapidly than the demand for primary energy, especially in developing countries. As shown in Fig. 3, in 1981 about 27% of the world primary energy consumption was used to produce electricity; by 2000, this figure is expected to increase to about 35%. In the developing countries only 17% of primary energy was used for electricity production in 1981, but this is expected to increase to the present world average by the year 2000. Considering that demand for

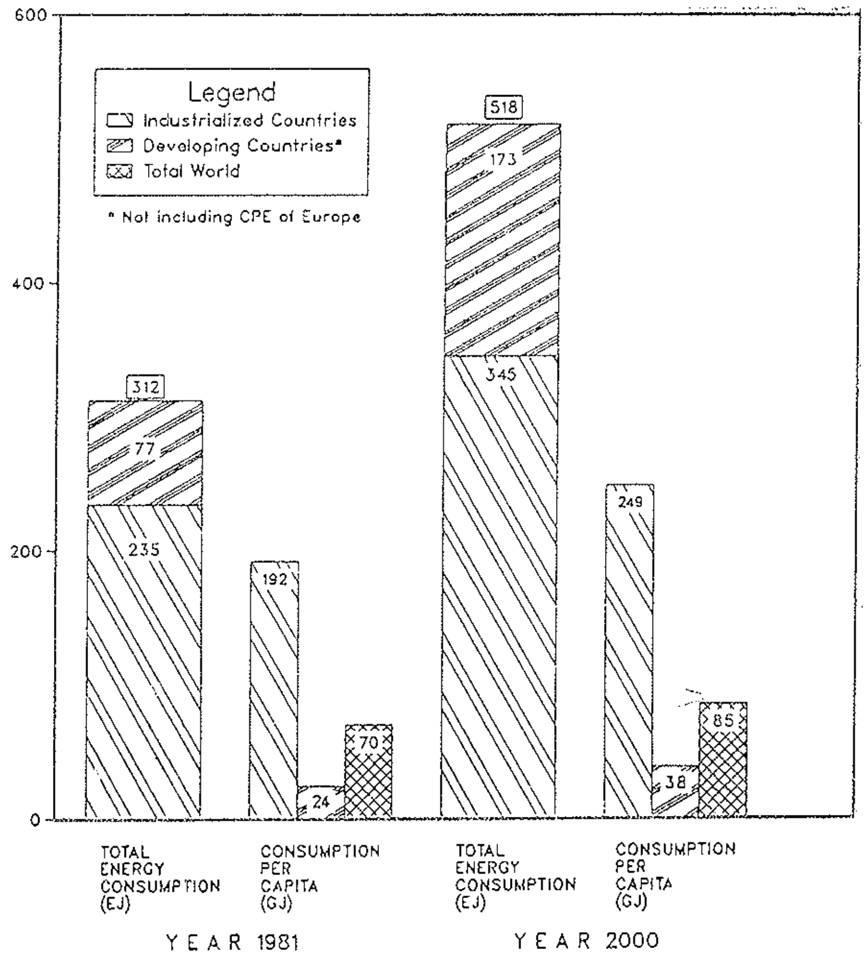


FIG. 1. Total and Per Capita Consumption of Energy.

primary energy in developing countries may double during the period from 1981 to 2000, electricity consumption might increase by a factor of 4 in this period compared to a world-wide increase by a factor of around 2,5.

In developing countries the larger increase of electricity penetration into the market is mainly re-inforced by the fast growing urbanization where only industrialization would help to provide a reasonable standard of living. We have to realize that at least 12-15 cities of more than 10 million people will grow in the developing world in the late 1990s. As a result, in the year 2000, approximately 50% of the world population will live in highly urbanized areas, most of them in the developing world. These will certainly require highly centralized supply systems and will rule out the possibility to use non-commercial sources of energy and decentralized supply systems. Consequently, electricity produced by large centralized supply systems is the obvious solution to a growing fraction of the population. Today and in the foreseeable future only gas, coal and nuclear power offer significant alternatives to the present electricity supply by oil and hydro in developing countries. This is the conclusion not just of the IAEA but also of the World Energy Conference and other international organizations.

However, in spite of the expected growth, the majority of developing countries have and will continue to have very low electricity consumption levels.

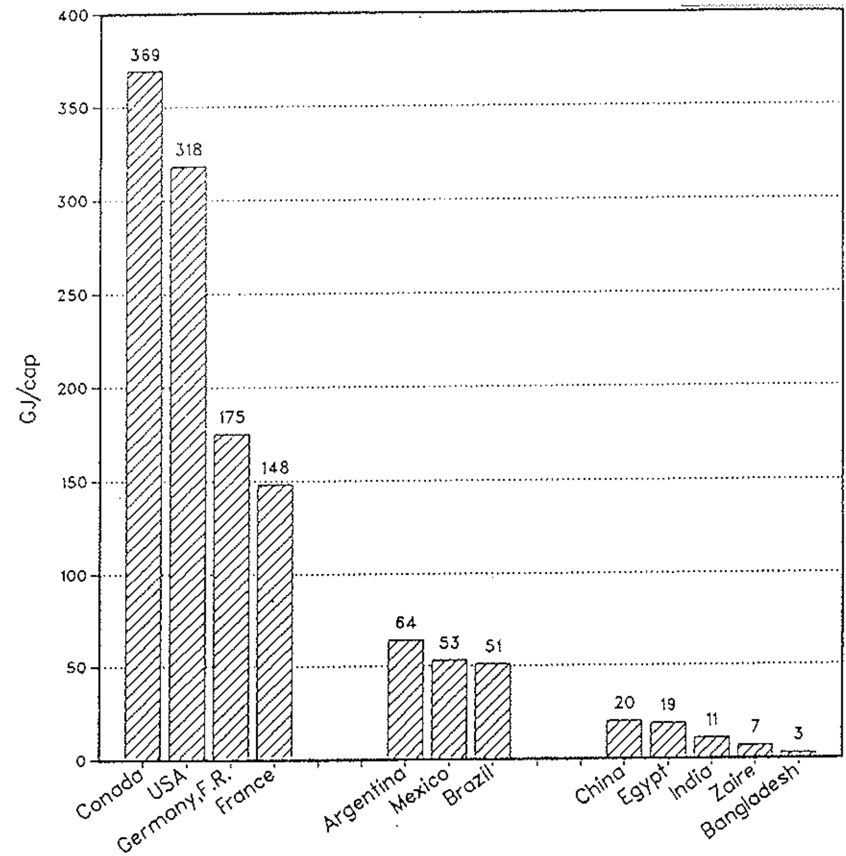


FIG. 2. Per Capita Consumption of Primary Energy in Selected Countries during 1981.

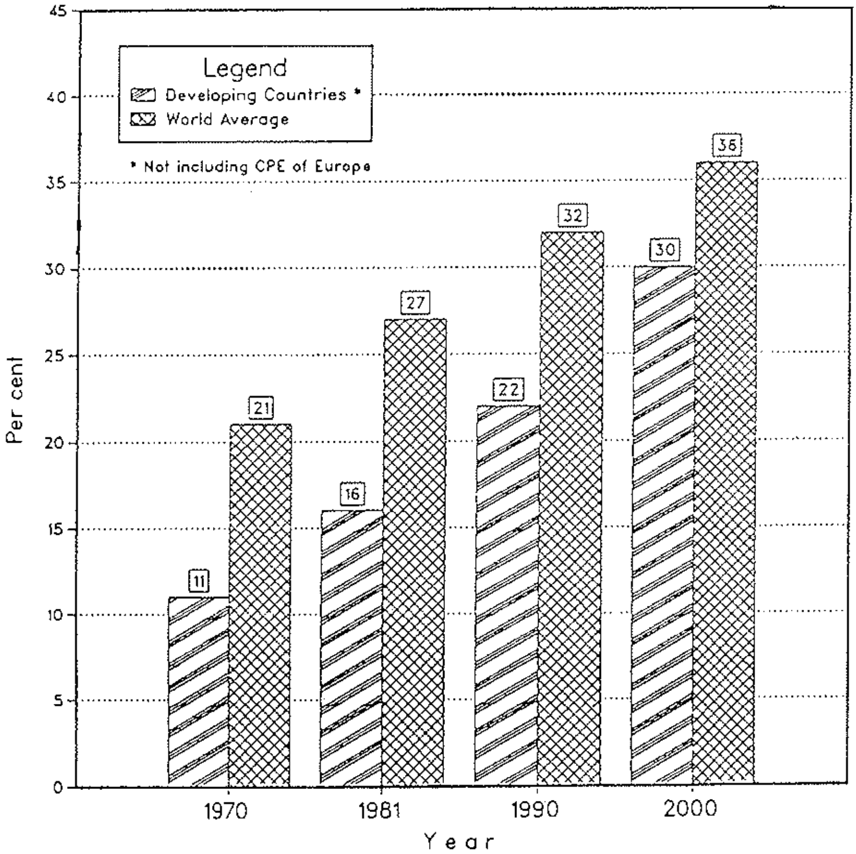


FIG. 3. Percentage of Total Energy Consumption used for Electricity Generation.

As can be seen in Table 1 eight developing countries accounted for about 62% of the total electricity production in the developing world during 1981. All have on-going nuclear power programmes. The remaining 38% of electricity production was distributed among 153 countries. The average 2,8 TWhe per country corresponds to 1,7% of the total electricity production in India.

The total electricity production of all 161 developing countries of around 1300 TWhe corresponds to only around 50% of the electricity produced in the USA in 1981.

May I now turn to nuclear power and its role for developing countries. I would start by stating that the current status and possible future develop-

TABLE 1 - *Electricity Production in Developing Countries * during 1981.*

	Electricity Production TW.h(e)	Percent of Total Production in DC's
1. China, People's Rep. of	309	23
2. Brazil	140	11
3. India	117	9
4. Mexico	74	6
5. Yugoslavia	57	4
6. Korea, Rep. of	43	3
7. Taiwan	42	3
8. Argentina	38	3
Sub-total	820	62
Total all others (153 countries)	502	38
Total developing countries (161 countries)	1,322	100

* Not including those in the Centrally Planned Economies (CPE) in Europe.
Source: IAEA Energy and Economic Data Bank (EEBD).

ment of nuclear power clearly indicate their importance for world-wide energy and especially electricity supply as one of the technically and economically competitive resources, immediately available on a large industrial scale.

As shown in Table 2, at the end of 1983 there were 317 nuclear power plants with a total capacity of 191 GWe in operation in 25 countries. Further 209 nuclear power plants with a total capacity of 194 GWe were under construction world-wide.

During 1983, nuclear power plants produced about 12% of the world's electricity. Thus, it must be recognized that the nuclear contribution is already an impressive achievement. If the 1000 TWh of electricity produced by nuclear plants during 1983 had been produced by fossil-fired plants these plants would have burned fuels equivalent to about 230 million tons of oil equivalent (MTOE) annually (about 4 million barrels per day). In other words, during 1983 nuclear power plants saved fossil fuels equivalent to over half of Saudi Arabia's annual oil production or around 6% of the world oil production.

How about the nuclear situation in developing countries?

As seen in Fig. 4, at the end of 1983, only seven developing countries,

TABLE 2 - *Nuclear Power Status at the end of 1983.*

Country Name	In Operation		Under Construction		Electricity Supplied by Nuclear Power Reactors in 1983	
	No of Units	Total MW(e)	No of Units	Total MW(e)	TW.h(e)	% of Total
Argentina	2	935	1	692	3.4	8.8
Belgium	6	3473	2	2012	22.8	45.7
Brazil	1	626	1	1245	0.2	0.1
Bulgaria	4	1632	2	1906	12.3	32.3
Canada	15	8303	8	5925	46.3	12.9
China			1	300		
Cuba			2	816		
Czechoslovakia	2	762	9	4354	5.7	8.0
Finland	4	2206			16.7	41.5
France	36	26903	25	29200	136.9	48.3
German D.R.	5	1694			(11)	(12)
Germany, F.R.	16	11110	11	11908	62.4	17.8
Hungary	1	408	3	1224	2.1	10.0
India	5	1030	5	1100	2.9	2.2
Italy	3	1232	3	1999	5.6	3.2
Japan	28	19023	10	10022	106.5	(20)
Korea, Rep. of	3	1789	6	5474	9.0	18.4
Mexico			2	1308		
Netherlands	2	501			3.4	5.9
Pakistan	1	125			0.2	1.0
Philippines			1	621		
Poland			2	880		
Romania			2	1320		
South Africa			2	1842		
Spain	6	3760	9	8369	10.2	9.1
Sweden	10	7355	2	2100	39.1	36.9
Switzerland	4	1940	1	942	14.8	29.3
Taiwan	4	3110	2	1814	18.9	(36)
UK	35	8304	7	4252	43.9	17.0
USA	80	63315	49	54228	292.0	12.7
USSR	43	20671	41	38001	(113)	(8)
Yugoslavia	1	632			3.7	5.8
World Total	317	190839	209	193854	(1000)	(12)

Note: Values in parentheses are IAEA estimates.
Source: IAEA PRIS, Report XBLMQ70.

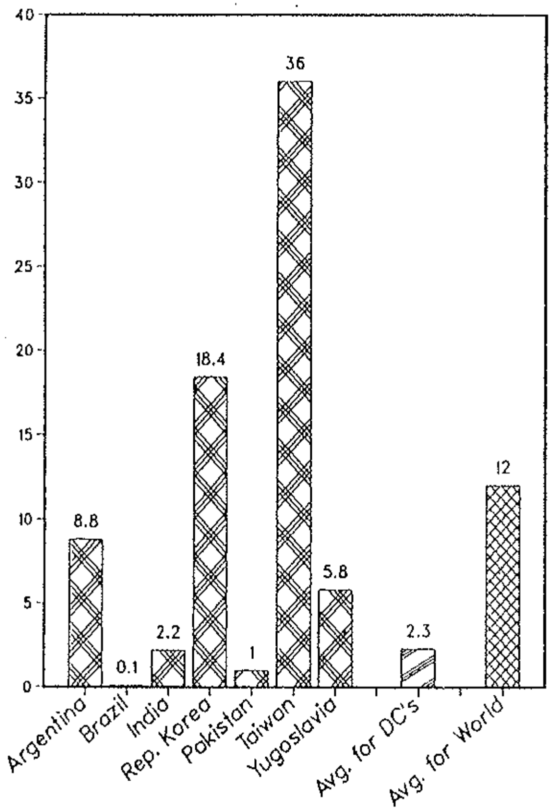


FIG. 4(a). Nuclear Share of Total Electricity Generation in Developing Countries during 1983 (Percent of Total).

namely Argentina, Brazil, India, Republic of Korea, Pakistan, Taiwan and Yugoslavia, had 17 nuclear power plants in operation with a total capacity of more than 8000 MWe, providing 2,3% of the total electricity generation in developing countries. By comparison, for the total world, nuclear energy contributes about 12% of total electricity generation. Referring to Table 3, as of 1 January 1984, 21 plants with more than 13000 MWe capacity were under construction or on order in most of these seven countries plus People's Republic of China, Cuba, Mexico and the Philippines. At least three other countries (Egypt, Turkey, Libya) have plants in the planning stage.

Some other countries, including Bangladesh, Greece, Indonesia, Portugal, Syria, Thailand and Tunisia have stated their intention to introduce

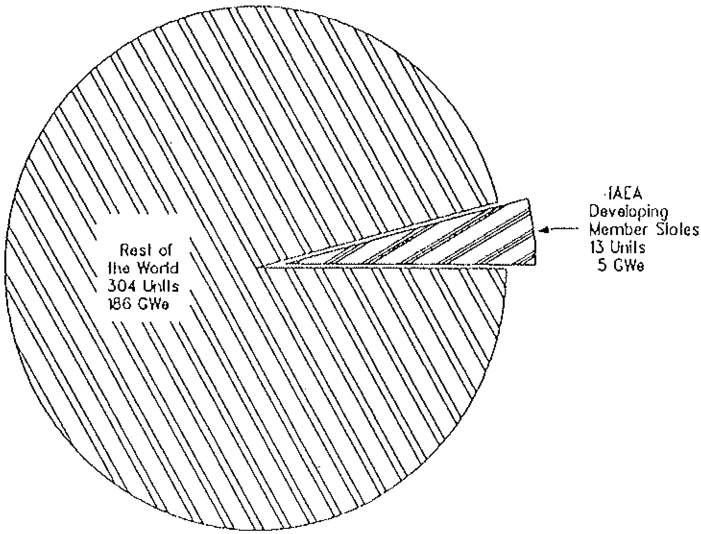


FIG. 4(b). Power Reactors in Operation as of Dec. 1983.

nuclear power, but have not yet made definite commitments to nuclear power plant construction, mainly due to financing problems.

As a result, by the year 2000 up to an additional 5 or a total of around 15 developing countries may have a chance to use nuclear power plants for their increasing electricity demand, corresponding to a total nuclear capacity of around 50 GWe or 6% of the total electricity generation in developing countries. The corresponding figures for industrialized countries, including CPE Europe, will be between 400 and 600 GWe or around 25% of the total electricity generation.

What are the reasons which are limiting the growth of nuclear power in developing countries, and which measures are needed to further increase the peaceful use of nuclear energy in these countries?

An important factor limiting the possible introduction of nuclear power in a large number of developing countries has in most cases been their small and fragmented transmission grids and the present unavailability of proven nuclear power plants in a size range of 200 to 400 MWe which could be used in these grids, with the exception of the USSR standardized 400 MWe PWR type, which is still built and exported.

A generally used, but also a rather simplified, rule-of-thumb is that a single power generating unit should not exceed 10% of the total generating

TABLE 3 - *Nuclear Power Plants in Developing Countries* * (as of 31 December 1983).

Country	Operating		Under Construction	
	No. of Units	Capacity MW(e)	No. of Units	Capacity MW(e)
Argentina	2	935	1	692
Brazil	1	626	1	1245
China, P. R.	—	—	1	300
Cuba	—	—	2	816
India	5	1030	5	1100
Iran, Isl. Rep. [1]				
Korea, Rep. of	3	1789	6	5474
Mexico	—	—	2	1308
Pakistan	1	125	—	—
Philippines	—	—	1	621
Taiwan	4	3110	2	1814
Yugoslavia	1	632	—	—
Total	17	8247	21	13370

* Not including those in the Centrally Planned Economies (CPE) in Europe.

[1] In the Islamic Republic of Iran, construction on 4 units has been suspended, but resumption of work on 2 units is under negotiation.

Source: IAEA Power Reactor Information System (PRIS).

capacity of all plants on the transmission grids, for reasons of stability of the electricity supply. If one applies this rule to Member States of the IAEA, the number of countries which would be able to use nuclear power plants in various size ranges are presented in Fig. 5.

— At present, the power grids in 37 IAEA Member States could accept nuclear units of 600-1300 MWe presently available on the market whereas only 24 actually have operating power plants.

— Some 15 countries, all developing, could use units in the 200-600 MWe ranges as their biggest units.

This seems to be one indication of the potential market for smaller nuclear power plants, if they were economically competitive and more widely availahle, but this also applies for other types of power plants.

However, poor economics, the limited availability of mature designs and other, mostly technical, uncertainties in the decision-making process have kept suppliers' and buyers' interests in small and medium power reactors (SMPRs) at a rather modest level.

To assist in this area and bridge existing information gaps, the IAEA has started a study which brings together the three major partners in any future SMPR plant, namely buyers, suppliers and the financing institutions. This study is intended to analyse the technical and economic grounds for SMPRs and to identify the size of the possible market for this type of nuclear power plants in the future.

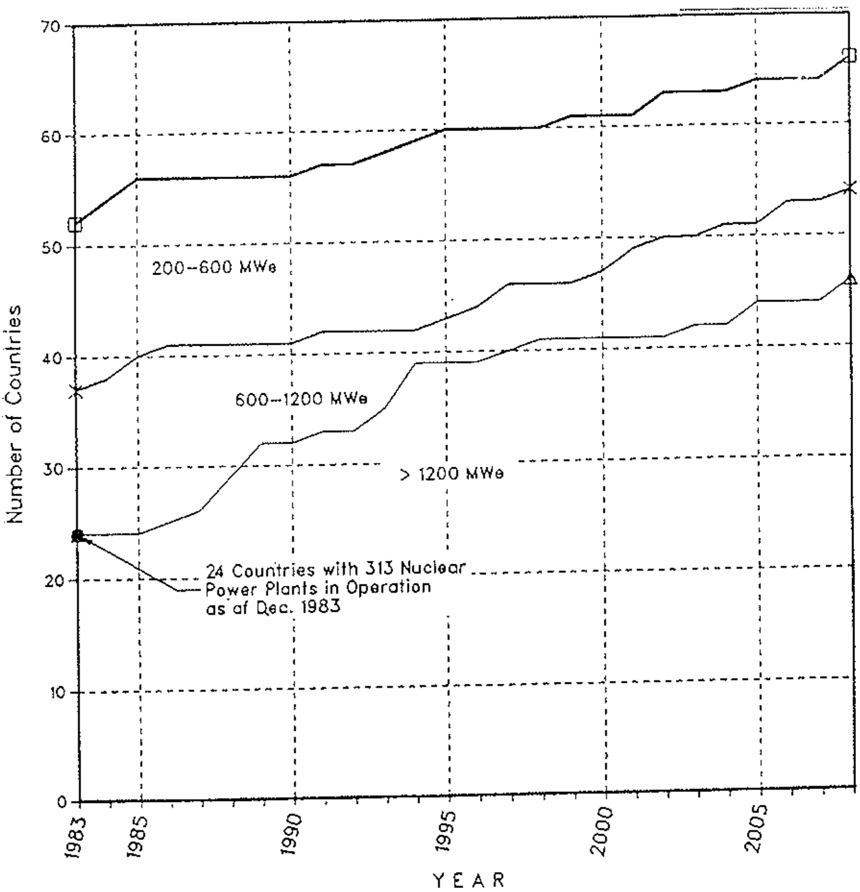


FIG. 5. Number of IAEA Member States Able to Use Nuclear Power Plants as a Function of Plant Size.

It should, however, be recognized that going nuclear with a small reactor will require nearly the same commitments to a high technology as in the large reactor case, namely in respect of manpower, infrastructure, transfer of technology and financing.

The technical complexities and unique safety requirements of nuclear power programmes, as well as the economic consequences of unreliable operation, make it imperative that highly qualified manpower be available from the very beginning of the programme, which normally requires a lead time of at least ten years or more.

Development of the necessary industrial infrastructures is another important prerequisite, which, however, should be directly inter-related to the country's overall industrial development programme and the general energy demand and supply situation. The entirely domestic development of highly complex technologies on a reasonable time schedule would not be feasible in most developing countries. Acquisition from abroad is the commonly used manner to obtain this new technology.

It must be recognized that nuclear power is a capital-intensive energy source with nuclear power plant investment costs contributing up to 80% of the total nuclear generation costs. Because of the high investment requirements, financing proves presently to be a most important limiting factor for nuclear power programmes, particularly in developing countries where the present economic situation is extremely precarious. It is tragic that those developing countries which will need nuclear power and which have — or are close to having — the infrastructure needed to support a nuclear power programme are now in such financial straits that their nuclear projects have to he delayed or cancelled. The economic difficulties of most developing countries are to a large extent caused by the high oil import bills, nonetheless oil will remain the most important source for energy and electricity generation in the majority of developing countries.

Without going into details, the total investment for a 600-900 MWe nuclear power plant might be between 1.5 and 3.0 billion US $, considering capital investment costs between 2500 and 3500 US $/kWe installed capacity, depending on costs for development of the infrastructure, including expansion of the transmission and distribution system and a possible transition to a higher voltage level. Thus, it is apparent that the financing of a nuclear power programme will require suitable long-term financing arrangements in order to assure that the impact on the domestic economy would be made acceptable during the long lead times until the benefits from the low fuelling costs begin to provide economic benefits.

It must also be recognized that the nuclear power programme is only one of the several development programmes which will compete for the available investment funds and that the development of nuclear power should not exclude the possibility of other options and technologies appropriate to a specific country.

So far, nearly all imported nuclear power plants in developing countries were financed through special bilateral arrangements between the supplier and buyer. The present economic situation makes it difficult for the ever increasing investment costs to be financed by only one supplier under acceptable conditions for the buyer.

A closer co-operation between industrialized countries might be a possible solution by sharing supply of components and financing guarantees between at least two or more industrialized countries, as the present multilateral negotiations for the first nuclear power plant in Turkey illustrate.

On the other hand, international financing, e.g. by the World Bank, can realistically not be expected to a large extent within the foreseeable future. As a result, many nuclear projects in developing countries will be delayed for a considerable time due to purely financing problems and multilateral financing might be the only solution to the problem.

In this context, the economic competitive situation of nuclear power should be briefly summarized, considering that the costs of constructing nuclear power plants have risen very rapidly during the past decade, leading many critics of nuclear power to charge that nuclear power plants are uneconomic. However, studies carried out by AIF in the USA, by UNIPEDE in Europe and by the IAEA (Fig. 6) all reach the conclusion that, in spite of their rising costs. average electricity generating costs of nuclear power plants in all countries are very much lower than those of oil-fired plants and, in most situations, in the size range of 600-1200 MWe also substantially below generation costs of coal-fired plants.

Finally, nuclear power application and the corresponding long-term assurance of fuel supply and fuel service are strongly linked to major considerations of international policies. Nuclear energy has a unique characteristic, namely that its peaceful use is unavoidably accompanied by the production of large quantities of material which could be used for the manufacture of nuclear weapons. The concern about possible nuclear weapons proliferation has always had to be balanced carefully against

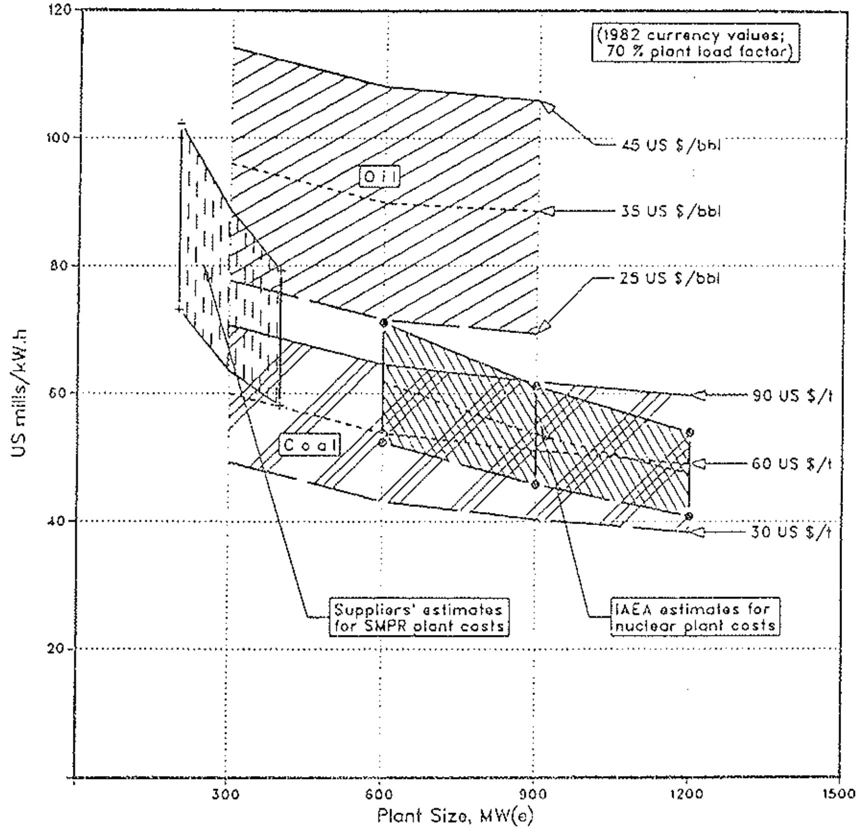


FIG. 6. Estimated Cost of Electricity Generated by Nuclear, Coal and Oil Power Plants Starting Operation in 1990.

potential benefits from the expansion of nuclear power. As a result, the system of agreements and treaties set up to ensure non-proliferation has itself shown a steady evolution towards a more generally acceptable and applicable non-proliferation regime, now mainly based on the Treaty of the Non-Proliferation of Nuclear Weapons (NPT) and also on the Tlatelolco Treaty for the Prohibition of Nuclear Weapons in Latin America. Both treaties established a central system and require the conclusion by each State of a safeguards agreement with the IAEA covering all nuclear activities in the State — present and future.

At present, 80 of the 112 Member States of the IAEA are developing countries and 63 of those are parties to either the NPT or the Tlatelolco treaty or both. Considering the generally accepted complementary nature of assurance of nuclear supply and non-proliferation, there is every reason to encourage the remaining few countries operating nuclear power plants or embarking upon a nuclear programme, to accept full scope safeguards, whether under existing or new treaty arrangements, such as regional nuclear-free zones.

We have to understand that the main constraints to nuclear trade and transfer of technology are political and not technical. Removal of these constraints can be assured only if there is a strong and efficient international safeguard system commanding universal acceptance and respect.

Conclusions

If some of the problems and constraints mentioned above can be solved, by the year 2000 some additional developing countries may have a realistic chance to use nuclear energy to meet their increasing electricity demand.

We should, however, understand that the most important condition to use the nuclear option is a clear decision to be taken by the Government at the policy level, based upon an extensive analysis of the future energy supply and demand situation, in order to plan as early as possible all actions to be needed for the implementation of nuclear power which requires a new dimension of qualified manpower, infrastructure and financing.

It is, therefore, the major task of the IAEA to assist its developing Member States in all aspects of the planning, implementation and safe and economic operation of nuclear power plants through special missions, planning studies, training courses and practical training and also through the preparation and publication of guidebooks and manuals and the development of internationally accepted Safety Codes and Guides.

We also have to understand that the solution of the energy problem of the developing countries in general and the further expansion of the peaceful use of nuclear energy, have an ever increasing international dimension. It is hoped that industrialized countries as well as regional and international organizations could co-operate more actively to remove some of the difficulties and limitations we are presently faced with.

Based on our experience these international measures could be:

— to provide developing countries with detailed and reliable methodologies for an assessment of the future energy demand and supply;

— to provide additional assurance for the long-term supply of fuel, materials and equipment and transfer of technology; unavoidably coupled with non-proliferation assurances;

— to establish regional co-operation for the development and application of energy resources, including grid interconnections and transport systems.

LARGE SCALE ENERGY SYSTEMS

WA KALENGA MALU
University of Zaïre
Kinshasa, Zaïre

PART I

THE INGA HYDRO-ELECTRIC PLANT IN ZAÏRE

ABSTRACT

In the predominant hydro-electric energy system of Zaïre, the Inga hydro-electric site plays a major role taking into account its size, its exceptional characteristics and the prevailing hydrological conditions in the country. The plant can operate with high load factor, generate electricity at a low overall cost at the bus-bar plant gate.

The competitiveness of the project is however dependent on the general infrastructure needed not only to transport and distribute energy but also to service big energy intensive industries.

The paper reviews the main problems and constraints facing the Inga hydro-electric site and affecting its competitiveness. It presents the main characteristics of the Inga Master plan devised by Zaïre to exploit the enormous energy resource of the site.

I.1. INTRODUCTION

Hydro-electric power is the only renewable commercial energy source that is available now on a large scale throughout the World.

As an energy source, water power stands apart from the other renewable energy forms:

— it is a flexible, mainly continuous system, that can readily go into the base load of utilities;

— it can be implemented economically in various sizes depending on the site;

— the technology involved is well established and basically simple in concept, implementation, maintenance and operation;

— the industrial infrastructure for the manufacture of various equipment (generator, turbine...) is well established in many countries;

— environmental impact is manageable and for most cases minimal;

— side benefits in the form of flood control, irrigation, river transportation can add to the value of the project.

Unfortunately hydro-power is site-specific. This usually means that one has to resort to costly transmission lines in order to match the production and consumption of energy. It is also capital as well as labor intensive, depending on its size, location and on the solution used for the construction of the dam.

If most of the easily accessible high to moderate head sites have already been developed in the industrialized countries, such is not the case in most of the developing countries of Africa. As shown in Table 1, the hydropower potentialities of the Sub-Saharan African countries are by any standard huge.

This considerable hydro-power potentiality remains for the main part undeveloped due to a combination of factors. Most of the countries in the region do not have sufficient demand to support large hydro-power development because population and per capita energy consumption are low. Such load that exists is more often than not located far away from the most promising site. The general infrastructure to support energy intensive industries, such as railroads, roads, ports, does not exist. Finally one has to cope with the financial and management problems related to any good size energy project.

To solve some of these problems, one can:

a) create a load near the site by way of large energy intensive industries;

b) transfer energy using either a long distance high capacity power transmission line, or some other energy vectors such as hydrogen or enriched uranium;

TABLE 1 - *Hydro-power potentialities of selected Sub-Saharan African countries* (see references [1 to 7]).

Country	Hydro-power potentialities (MW)	River	Main site: Name of the site	Main site: Status of the power plant *	Installed capacity (MW)
Zaïre	132.000	Zaïre	Inga I and II	B	1.750
			Inga III and IV	P	5.330
			Grand Inga	P	34.500
Zambia	3.834	Kafue	Kafue	B	600
		Zambese	Kariba II	B	600
Zimbabwe	5.000	Zambese	Kariba I	B	705
Mozambique	11.920	Zambese	Cabora-Bassa	B	1.200
			Cabora-Bassa	P	3.600
Congo (Rép. Congo)	9.040	Kouilu	Sounda	P	280-830
Gabon	17.520	M'bei	Tshimbela I	B	280
		M'bei	Kingele I, II, III	P	150
		Ogone	Pouraba I and II	P	250
Cameroun	22.960	Sananga	Edea	B	250
		Sananga	Song-Loulou	P	400
		Sananga	Nachtigal	P	200
		Nyong	Njock	P	270
Ghana	1.615	Volta	Akkosombo	B	912
		Volta	Bui	P	180-400
Guinea	6.400	Konkoure	Suajiti	P	700
		Bafung	Koukontamba	B	100
Angola	9.664	Cuenze	—	P	369
		Cunene	—	P	
Nigeria	4.800	Niger	Kainji	B-P	240-520
		Niger	Lokoja	P	2.000
Senegal	4.800	Senegal	Galongo	P	300
Ivory Coast	1.100	Sassandra	Soudre	P	250

* P = Planned; B = Built or under construction.

c) share the energy produced between neighboring countries by way of a general interconnected power grid.

All these solutions have been or are being actively considered and implemented by Zaïre in the framework of the Inga Master plan.

The first part of this paper will concern itself with the merits and constraints of the Inga Master plan. After a brief outline of the exceptional characteristics of the site, the paper will discuss various options to solve the difficult problem of matching the production and consumption of energy generated in a megaproject such as the Inga hydro-power site.

Taking into account the difficulties arising in the implementation of the Inga Master plan, which seem to be related in part to the size of the project, it becomes appropriate to ask oneself the following question: How big and still beautiful is the developing countries' energy sector?

This question will be the main concern of the second part of the paper. To-day one is witnessing the failure of some big energy ventures in the developed world. The case of nuclear energy in the USA is a good example. In the light of the size of the Inga hydro-power project, it is therefore interesting to reconsider in general the well-known "size effect" taking into account managerial, financial, economic and technological constraints prevailing in current competitive and poor international environment. One comes here to a fundamental issue of macro-engineering and macro-economy: "the economy of scale". Fresh perspectives and innovative thinking are needed to meet the challenges and constraints involved in applying macro-engineering approach in the current context of low energy demand and high interest rates.

Besides the minimization of over-all power generating cost, some other requirements such as capital, foreign currency, quality of managerial expertise, safety measures, licensing codes are of vital interest.

Besides the "size effect", one can also consider the "series effect". The basic idea here stems from the following considerations:

1. Capital cost of a power plant does not vary uniformly with capacity but rather changes by a succession of steps, some large, some small, as change in the design and technology as well as selection of major components are made to achieve the electrical capability desired;

2. There are cost components that do not vary directly with size such as those associated with special site situation, construction practice scheduling, availability of labour, nature of financing, licensing regulations

and the general economic climate over the time of construction and even over the lifetime of the project;

3. The prevailing general economic climate of low demand, high interest rates, concern over the environment and safety, is dominated by what one can call an "uncertainty factor";

4. Traditional correlation of "size effect" and "cost of incremental capacity" becomes somewhat clouded and is no longer as useful as it was as a guide in utility system expansion planning. The "cost-capability" relationship is but one factor and is most useful when balanced against "series effect" taking into account all other factors including those that are not size sensitive.

It is all these considerations that will be discussed in order to find out the merit and the constraints of the "size effect".

I.2. The Inga hydro-power master plan

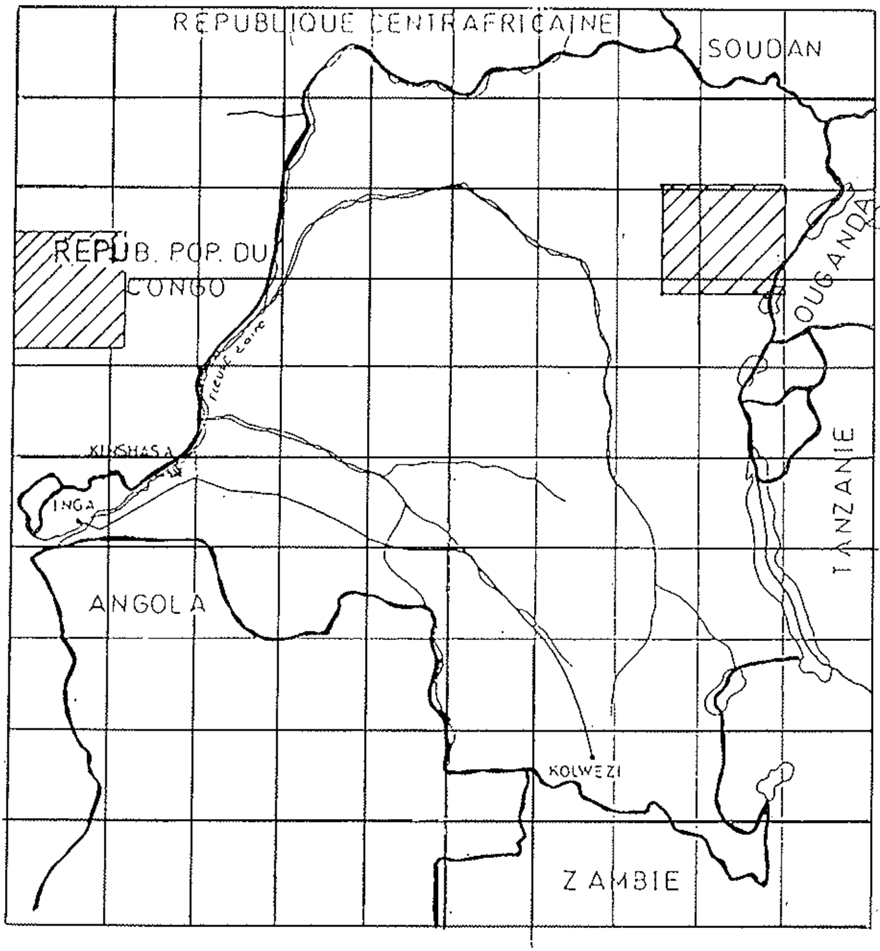
A. *The Inga dam*

The hydro-electric potentialities of Zaïre are important. With 774.000 Gwh/year Zaïre ranks third after China and Russia if one considers the energy that can be generated in an average year. It moves up to first place on the basis of guaranteed energy that can be generated in a low water year (631.000 Gwh/year at 98% guaranteed low water flow rate of about 26.500 m^3/sec); [4, 5, 6].

Sixty-five percent of Zaïre's hydro-electric resources are concentrated on a 350 km length section at the lower end of the Zaïre river, between the towns of Kinshasa and Matadi. Three main sites have been identified: Matadi site (installed and garanteed capacity equal respectively to 12.600 MW and 10.040 MW), Pioka site (installed and guaranteed capacity equal respectively to 22.240 MW and 20.170 MW), Inga site (installed and guaranteed capacity equal to respectively 39.000 MW and 34.800 MW) (see map 1) [4].

B. *Transmission lines*

Closely connected with the Inga II dam is the High Voltage Direct Current (HVDC) transmission line between the hydro-electric dam and the town of Kolwezi in the Shaba copper mining region (see map 1).



Echelle: 1/13.000.000

Map 1.

With a length of 1.700 km, the Inga-Shaba HVDC link is by far the longest in the World. The basic characteristic of the HVDC link is presented at table 3, [11, 12]. Table 4 gives the existing or projected transmission lines connected with the Inga master plan.

TABLE 2 - *Inga hydro-power site: capital cost, installed capacity, specific cost.*

Status Phases	Status	Installed capacity (MW) (a)	Capital cost (10^6 $) Historical (mixed $) (b)	Capital cost (10^6 $) Escalated ($ 1982) (c)	Specific power cost (KWh) Historical (mixed $) (b)	Specific power cost (KWh) Escalated ($ 1982) (c)
Inga I	Built (1972)	350	125 (1972)	861-895	357 (1972)	492-511
Inga II	Built (1982)	1.400	397 (1982)		283 (1982)	
Inga III A	Planned	1.200-1.500	400-589		266-490 (d)	
Inga III B	Planned	950-1.500	356		237-374 (d)	
Inga III C	Planned	1.200	502		41 (d)	
Inga IV	Planned	2.330-3.000	1.340		466-575 (d)	
Grand Inga	Planned	34.140-39.000	2.976		76-98 (d)	

(a) The uncertainty is due to variations in schema.
(b) The costs for Inga III to Grand Inga are estimated costs in $ 1974, excluding financial cost (reference [6 and 12]).
(c) The discount or escalated rates are 7%, 9% and 11% (see reference [9]).
(d) Estimated cost in $ 1974.

C. *The problem of matching the production and the consumption of energy in the Inga zone of influence*

Out of an installed capacity of 1.750 MW, 330 MW or 19% are now being used with 160 MW going to the Shaba region using the HVDC transmission line.

These figures under-score the importance of a major effort, under way for many years in Zaïre, to increase the demand of energy in the Inga zone.

The decision in the mid sixties, to build Inga I, the first stage of the project, was based on the need to relieve the power shortage forecasted for Kinshasa, the main manufacturing town of the country [13].

The decision in the early seventies to build Inga II and the Inga-Shaba HVDC transmission line was based on the need to relieve the power supply and energy shortages anticipated for the copper mining region of Shaba [14].

Taking into account development plans of the copper industries in the Shaba region, which were aiming for a total production of 910.000

TABLE 3 - *Inga-Shaba HVDC transmission line.*

Items	First stage	Interim stage	Final stage
1) Input capacity (MW)	560	840	1.120
2) output capacity (MW)	514	770	1.027
3) voltage (KV)	±500	±500	±500
4) transmission line rating	2.240	2.240	2.240
5) transmission distance (km)	1.700	1.700	1.700
6) number of poles	2	2	2
7) converter station:			
number	2	2	2
voltage (to the ground; KV)	±500	±500	±500
direct current (A)	560	560	560
converter per station	2	3	4
8) Cost:			
initial estimate (1976; 10^6 $)	360		
final cost (1982; 10^6 $)	776-869 (a)		
9) Starting date	1973		
Completion date	1982		

(a) estimated cost depending on the escalation rate (between 4% and 8% at constant dollars).

TABLE 4 - *Transmission lines connected to the Inga dam.*

	Transmission line	Status	Characteristic length (km)	voltage (kv)	power (MW)	Cost ($ 1982; 10^6 $) (a)
1	Inga-Kinshasa	B	200	200	200	37-53
2	Inga-Banana	P	150	220	200-570	51-64
3	Inga-Boma	P	80	220	200	27-35
4	Inga-Shaba	B	1.700	±500	560-1.120	776-869

(a) three escalated rates 4%, 6% and 8%, have been considered at constant dollars.

tons of copper by 1982, the energy deficit in the region was variously forecasted to reach the following level [12, 14]:

850 Gwh - 1.930 Gwh in 1977;
1.289 Gwh - 2.590 Gwh in 1980;
3.800 Gwh - 4.440 Gwh in 1991.

Inga II was the only alternative adequate to meet the power shortage of more or less 700 MW anticipated for 1991.

Due to a combination of factors related mainly to the recession in the industrialized world, which severely constrained developing countries' growth, the energy deficit did not materialise in the way and in the year that was forecast.

It was then necessary to devise a new Inga Master plan along the following three axes:

a) creation of an industrial "free zone" within a 200 km radius around Inga, with special advantages for both the price of electricity and taxes [15].

b) creation of an African electrical common market which will prefigure an African economic common market [16].

c) production of hydrogen as a secondary energy carrier [5].

D. *The "Inga Free Zone"*

The first axis of the Inga Master plan is the establishment in 1981 of a "free zone". Within the zone the price of electricity is set by law to be equal to the "return cost" at the point of furnishing, which can he located anywhere within a 200 km radius from Inga. This "return cost" is supposed to be much less than the "Short Run Marginal Cost (SRMC)"; it will eventually merge with the "Long Run Marginal Cost (LRMC)" when the Inga dam becomes saturated [17, 9].

The LRMC is forecasted to remain low for all the phases of the Inga project because of the exceptional topographical characteristics of Inga which allow a gradual hydro-electric development of the site up to the final total installed capacity of more than 34.000 MW at a decreasing average cost of energy (see table 2).

Attracted by the economic conditions in the free zone, several electricity intensive industries are negotiating with the Zaïre government, among them "Aluzaïre" for the production of aluminium (3.150 Gwh/year; 150.000 Tons/year initially) and "Electro-Fertilizer International" for the production of ammonia using electrolytic hydrogen (2.500 Gwh/year; 285.600 T/year).

It should be noted that on a purely energetic base the ammonia plant is particularly interesting because it is one of the most energy intensive industries that can be adapted to the use of interruptible or off peak power, that is for electrical load-leveling purposes [19].

Table 5 gives a forecast of the aggregate demand of energy in the free zone under 3 different scenarios: high demand (HD); Medium demand (MD) and Low demand (LD). The three scenarios differ mainly in the anticipated starting date of the big energy intensive industries interested in the free zone and in the rate of growth of the demand of energy in the copper mining province of Shaba (3%/year growth rate for HD, 2%/year for MD and 1,5%/year growth for LD scenario) [9, 18].

Taking into account the guaranteed power in the "free zone" (1.800 MW including the Zongo dam: 70 MW), the loss in the network (around 10%) and a capacity factor of 80%, the net available energy in the "free zone" is equal to about 11.350 Gwh. It is seen that saturation of the bydro-power plant in the "free zone" will be reached in 1994 in tbe HD scenario, in 1999 in the MD scenario, in 2005 in the LD scenario. The last two scenarios are the most likely.

E. *Electrolytic hydrogen as a secondary energy carrier*

The second axis of the Inga Master plan concerns the setting up of of a hydrogen economy in the country [5]. The technology of water electrolysis has made major advances over the years [20]. It is likely that progress will continue as the price of natural gas and the interest in

TABLE 5 - *Demand of electrical energy in the "free zone" (Gwh).*

Year	HD scenario	MD scenario	LD scenario
1985	2.030	1.900	1.710
1990	8.970	2.530	1.960
1995	13.030	10.500	8.130
2000	14.900	12.960	9.470
2055	19.290	13.980	11.330

the fuel cell as a power plant increases [21]. Up to now the economy of the process, when compared to conventional reforming near a source of fuel (natural gas, naphtha, oil) is still not favorable. However, the coming of age of advanced technology, which permits the use of higher current density and low voltage cell, seems to indicate that the process is becoming competitive in many areas of the world where cheap electrical energy exists [24, 25]. Furthermore its load leveling ability for power systems can be exploited if the need arises.

The simple chemistry of the hydrogen, oxygen and water system shows promise as an ideal fuel for the future and for a chemical heat pipe system. Indeed the manufacture of hydrogen from water, its distribution as a fuel and recycle of product water by naturally occurring meteorological and geographical phenomena constitute a natural chemical heat pipe [22].

To phase-in the hydrogen economy in Zaïre, the Inga Master plan considers three phases: the ammonia (fertilizer) phase, the methanol (CH_3OH) phase and the liquid or gaseous hydrogen phase. The first phase is already under way using both centralized energy system (Electro-Fertilizer International project (EFI)) and decentralized energy system (Elenza project). This last approach is under study using the advanced "poly-antimonic acid membrane in alkaline water electrolysis" technology developed in Belgium [23, 24]. In this technology, hydrogen is produced under pressure (40 kg/cm^2), with a consumption of 3 to 3,5 kWh/Nm^3 (versus 4,2 to 5,5 Kwh/Nm^3 for classical bipolar technology); higher current density up to 10 KAm^{-2} (versus 2 KAm^{-2}), higher temperature up to 120°C (instead of 90°C), lower cell voltage 1,5 to 1,6 volts (versus 2-2,2 volts).

Small units, down to a size of 50 t/day of ammonia, can be built economically using the advanced technology [24]. The specific cost of ammonia nitrite is 725 $/ton versus 705 $/ton for the EFI centralized solution [25].

The second phase of the projected hydrogen economy, that is the methanol phase, does not call for particular comments.

In the third phase of the hydrogen economy, hydrogen will be utilized as a secondary energy carrier. As a carrier of secondary energy hydrogen has the following advantages:

— complete compatibility with other gaseous energy carriers which permit a continuous transition from natural gas via SNG to hydrogen;

— the cost of long distance energy transmission by hydrogen using natural gas distribution equipment appears to be about one third to one tenth that of electricity. It poses however the problem of safety of welds [26];

— a close association with electricity is of importance for peak power management especially for hydropower, and as a practical way of overcoming the lack of congruence between power demand and power production (wind power for example [26];

— the emergence of thermochemical and photolytic hydrogen production opens the way for solar energy to become a global future energy option particularly for the developing countries in the world's belt of solar radiation [20, Vol. 1];

— it has indisputable ecological advantages as a natural chemical heat pipe [22].

F. *African electrical common market*

The third axis of the Inga Master plan concerns the creation of an interconnected African electric network with the Inga hydro-power plant playing a central role [16]. It is assumed, with reference to the European Common Market experience, that such an electric energy cooperation will lead to a better and rapid integration of the African economies and finally to a better political cooperation among the countries involved.

The basic idea is to take advantage of the experience gained with the construction of the long distance "Inga-Shaba" and "Cabora-Bassa (Mozambique) - Apollo" HVDC to start a general interconnection between the power grid of African countries extending from Mozambique in the South-East to Nigeria in the North-West through Zimbabwe, Zambia, Zaïre, R.P. Congo, Gabon, Cameroun with secondary lines extending to Angola, Burundi, Rwanda, Ivory Cost, and Ghana [27, 2].

The scheme is conceived in such a way that all the countries concerned are connected to a main HVDC line extending from Inga to Nigeria in the North and from Inga to Mozambique to the South using the existing Inga-Shaba HVDC. This is necessary in order to insure right of way requirements as well as the safety of the line. It is hoped that there will be as much as possible a two-way energy transfer involving each country depending on time (of days, months or years), on the status of power plants in each country and on weather conditions from one country to another.

Tentatively the following hydro sites will be linked by a main HVDC line (see table 1 and reference [2]):

a) *North-line*:

Zaïre (Inga)-R.P. Congo (Sounda)-Gabon (M'bei)	750 km
Gabor (M'bei)-Cameroun (Song-Loulou)	550 »
Cameroun (Song-Loulou)-Nigeria (Lokoja)	550 »
Nigeria (Lokoja)-Ghana (Akunsonbo)	700 »
Ghana (Akunsonbo)-Ivory Cost (Taabo)	500 »
	3.050 km

b) *South-line*:

Zaïre (Inga)-Zambia (Kafue)	2.200 km
Zambia (Kafue)-Zimbabwe (Kariba)	100 »
Zimbabwe (Kariba)-Mozambique (Cabora-Bassa)	1.000 »
	3.300 km

The total proposed interconnected power grid has an already installed power capacity well above 7.000 MW.

I.3. *Inga Master plan problems: the question of the price of electricity*

From the experience gained in the construction of the Inga hydroelectric plants and the implementation of the Inga Master plan, one can list the following problems affecting large scale energy systems in developing countries such as Zaïre:

a) the problem related to the forecast of energy demand;

b) the management and scheduling problems;

c) the infrastructure and related price of electricity problems.

A. *The forecast of energy demand problem*

The forecast of the demand of energy made in the sixties and early seventies for the so-called "zone d'influence d'Inga" has been shown to be too optimistic [14]. The main reason is of course the recession in the industrialized World which has severely constrained the development of the copper mining industry in the Shaba Region.

Taking into account the vast amount of capital expenditure required by any sizable energy project such as the Inga hydro-power plant, it is imperative to forecast energy demand as closely as possible. Unfortunately forecasting methods based on traditional econometric models that rely on stable trends and patterns, that is on the fatalistic approach, are showing themselves to become grossly inadequate in the prevailing uncertainty affecting socio-economic, scientific and technological parameters [28, 29, 31].

Historically evolving energy-use patterns are no longer valid in view of drastic changes in the current socio-economic order ushered in by the oil shock [32].

The simple "demand of energy-GNP" relationship for example is no longer valid because, among other things, of its instability and because it does not account for possible alteration in the underlying structural relationship between the consumption of energy and the economy. The introduction of the energy price into the estimated relationship was certainly a progress since the efficiency of energy use depends on the energy price. But, besides the difficulty of defining a real price of energy, price can induce technological change only when prices of all other factors, including energy, are constant and when the economy is functioning like a perfectly competitive equilibrium system, which is generally not the case [33, 34].

Generally the inadequacies of current forecast methods is due to a combination of factors, amongst them [29, 31]:

a) the application of outmoded and/or inappropriate forecasting models or approaches;

b) the imposition of erroneous or partially invalid assumptions, in particular the assumption of a competitive energy market;

c) the use of results from earlier outdated models into newer more valid models;

d) the failure to account for the social environmental factors which might buttress energy use or restrain the penetration of new forms of energy;

e) the problems created as a result of the diversity and complexity of new technologies.

B. *The management and scheduling problems*

Overall the scheduling and management on the production side of the Inga project did not pose particular problems. The Inga I and Inga II dams and power-houses were completed in time with no cost overrun. Such was not the case however for the Inga-Shaba HVDC transmission line which has experienced scheduling and cost overrun problems.

On the other hand, the load side of the project has encountered almost unsuperable burdens in spite of very favorable economic and fiscal conditions. The management and scheduling problems, here, are made that much more difficult by the assumption in industrial circles in developed countries that great political courage is required to plan large energy intensive industries in developing countries because of political instability, lack of technical skill, debt burden problems and/or lack of infrastructure. In the case of the Inga project, political instability and technical expertise are certainly not a problem. Debt burden problems are disposed of by one of the most liberal investment codes in the developing world and by additional generous privileges in the "free zone".

The lack of infrastructures is of course a major stumbling block in any developing country. Road, railroad, port facilities, electrical transmission lines require, in a country the size of Zaïre, vast outlays of scarce hard currencies. However if one considers, as he should, the hydro-electric plant as a part of the general infrastructure needed to supply the logistic support to a big industrial project, such as aluminium or fertilizer industries, then one must admit that sufficient infrastructures exist already in the free zone. The need for bigger facilities in port handling, and some additional road facilities are however still needed to accommodate the aluminium industry taking into account its size. One comes here to a major problem confronting any industrial management and scheduling exercise in a country the size of Zaïre: All things being equal big industrial projects require big infrastructures and therefore big financial requirements; and the bigger the industrial ventures, the bigger the constraints. This translates into a big overall cost of energy, if one wants to insure a positive internal rate of return on equity during the lifetime of the energy project with general infrastructures included.

Thus one encounters the serious problem of setting up a price of a unit of energy generated which must be at the same time attractive and remunerative.

C. *The problem of the price of energy*

The problem of the price of energy is an important and difficult one for many reasons. The first reason is of course the fact that the wrong price of energy can lead either to over-investment and waste or to under-investment and the additional cost of scarcity. Such a danger is embedded in the traditional accounting approach which is in fact a simple fatalistic approach.

The second reason is that energy pricing is one of the most effective demand management tools. Such management requirement leads to the notion of strict Short Run Marginal Cost (SRMC) and strict Long Run Marginal Cost (LRMC) [35]. This traditional electric power pricing policy in most countries is based on financial or accounting criteria, e.g. raising sufficient sales revenues to meet operating expenses and debt service requirement while providing a reasonable contribution toward the capital required for future power system expansion [17].

The third reason is related to the fact that, in practice, there does not exist a truly competitive energy market that excludes any normative policy choice. The notion of "shadow price" or "marginal opportunist cost" is connected to this fact [36, 17].

One considers, here, along with economic, technical and financial constraints or requisites, factors with a general social or even political utility such as environment considerations, social well being, basic political value, community self reliance. Unfortunately if such a teleological approach is to-day necessary and useful no recognized energy model using that approach, in conjunction or not with the classical approach, is available [31].

One of the reasons is simply that some of the objectives are mutually exclusive or inconsistent in spite of the fact that they all fit into a sound normative development policy.

One has therefore to resort to the notion of non strict-SRMC and LRMC, or opportunity cost. Strict LRMC and SRMC are not applicable in the Inga "free zone" for many reasons. Amongst them one can list the following:

— one has not a competitive electrical energy economy; that is the supply is not adjusted to the demand. The large excess supply capacity renders the long run system plan sub-optimal in the short run; that is LRMC is much different from the SRMC (which includes operation and maintenance cost) because of reduced capacity charges. This situation is compounded by the overall reduction in demand growth due to the economic recession and the cost of electrical appliances;

— there exist distorsions in the energy price in the country due to subsidization of substitute energy prices: kerosene for lighting and cooking in order to reduce the recourse to wood and charcoal; diesel for auto generation and transport;

— The production, transport and distribution system of energy is not optimal (supply at the least cost) because the power grid is partially interconnected only.

In theory when the system is optimally planned and operated (i.e. capacity and reliability are optimal), SRMC and LRMC coincide [17]. But this is difficult to achieve when system consumption increases by big increments due for example to the connection of big energy intensive industries (*).

For all these reasons and many others it was felt expedient as an interim stage before using LRMC to calculate the price of a unit of energy produced using the notion of "prix de revient" (return price) which can be related to the notion of non-strict LRMC.

The technique used is a variant of the discounted cash flow. The average cost of electricity is calculated as the ratio between the "present worth charge", "F", and the "present worth volume for energy generated", "G", during the lifetime of the Inga I and II plants [9].

One has:

$$P = \frac{F}{G}$$

with:

$$F = \sum_{t=1}^{N} \frac{(C_C + C_{OM})^t}{(1 + a)^t}$$ = present worth at start up of the total cost (capital, operation and maintenance)

$$G = \sum_{t=1}^{N} \frac{V(t)\,(1 + i)^t}{(1 + a)^t} = \sum_{t=1}^{N} (V(t)\,(\frac{1 + i}{1 + a})^t = \sum_{t=1}^{N} V(t)\,(1 + k)^t$$

Where:

— P is the "price of return" equal to the average return cost of electricity;

(*) It should be noted that LRMC may be defined broadly as the *incremental* cost of optimum adjustment in the system expansion plan and system operations attributable to an incremental demand increase which is sustained into the future.

— i = escalation rate (equal to the inflation rate in \$; 5,5% in the present case);

— a = discount rate (equal to 7%, 9%, 11% in current dollars; equal to 4%, 6%, 8% in constant dollars);

— t = the current year;

— N = lifetime of the project (set equal to 20, 30, 40, 50 years);

— V (t) = volume of expected sale of energy at year t (in Gwh) (incorporated the load factor at year t).

It is seen that G can be considered as the discounted energy over the lifetime of the plant.

The calculation is carried out in two stages, in order to get the "average cost of electricity" as the sum of the "unit generating cost" (at the plant gate bus-bar) and of the "unit transportation cost".

The "unit generating cost" is the range from 3,84 mills/Kwh (in \$ 1982) depending on the discount rate, lifetime of the plant, and the scenario. The most likely value falls between 7,66 mills/Kwh and 9,59 mills/Kwh.

The "unit transportation cost" in the free zone is in the range (0,90-3,32) mills/Kwh, with the most likely cost in the range (1,07-2,18) mills/Kwh.

The "unit transportation cost" with the Inga-Shaba HVDC link is in the range (8,6-24,07) mills/Kwh.

I.4. Conclusion

Without doubt, Zaïre possesses at the Inga hydro-electric site one of the most economical sources of electricity in the world. The exploitation of this renewable resource requires however large amounts of hard currency to produce, transport and distribute electricity and to build the general infrastructure needed by large intensive energy industries.

The low cost of producing electricity at Inga compensates somehow the cost of transporting it over long distances in order to start up a general interconnection between the power grid of African countries as a stepping stone for a close overall economic cooperation in Africa.

REFERENCES

[1] World bank, *L'énergie dans les pays en développement.* Washington DC (août 1980).

[2] GILLON L., *Ressources et vecteurs énergétiques en Afrique de l'Ouest.* Communication à l'Académie Royale des Sciences d'Outre-Mer, Belgique (1980).

[3] Various publications of CEA, Addis-Abéba, including: *Le développement de l'énergie dans les pays de la sous-région de l'Afrique de l'Ouest.* (CEA, 1966);*Le développement de l'énergie dans les six pays de la sous-région d'Afrique du Centre* (CEA, 1967).

[4] LIVADIOTI G., PENTA P., PIERINI C. and SAPPA M., *The hydro-electric potential of the lower course of the Zaïre River and possible use for the electric power. Proceedings of the 2nd World hydrogen Energy Conference,* Zurich, vol. 1, p. 173, 1978.

[5] MALU, WA KALENGA., *Hydrogen as a feedstock in chemical and petro-chemical: the case of Zaïre,* in T.N. Veziroglu, K. Fueki, T. Ohta, « Hydrogen energy progress », vol. 3 (1980) Pergamon Press, pp. 1273-1277.

[6] E.D.F., *Equipement du Grand Inga.* Rapport intérimaire (déc. 1974).

[7] Various publications of SNEL (Zaïre) including: CIFARHA M., *Données synthétiques sur les ressources hydro-électriques du Zaïre.* SNEL internal report (août 1983).

[8] SAPPA M., *Possible use of hydroelectric power of the lower course of Zaïre River,* in T.N. Veziroglu, K. Fueki, T. Ohta, « Hydrogen energy progress », vol. 3, Pergamon Press (1980), pp. 1373-1406.

[9] Sema énergie, *Etude des tarifs de l'énergie électrique applicables aux industries éligibles au régime de la Zone franche d'Inga.* Rapport provisoire, ZOFI (février 1983).

[10] Sicai, *Plan directeur de l'aménagement d'Inga,* 1977-1978, Rome.

[11] SNEL, *Inga-Shaba, ligne de transmission THTCC la plus longue du monde,* plaquette (1976).

[12] SNEL, *La production, la transmission et la distribution de l'énergie électrique au Zaïre.* Communication au colloque sur l'énergie, Kinshasa 25-28 février 1980, Code CNE/80/PE-SR-1/1.

[13] MALU, WA KALENGA., *Le problème du déficit énergétique de Kinshasa.* Monographie ONRD (1968), 60 pages.

[14] MALU, WA KALENGA., *Les solutions possibles du problème du déficit énergétique de la Région du Shaba en République du Zaïre.* Ed. ONRD (1972), 124 pages.

[15] « Ordonnance-Loi n. 81/010 d'avril 1981 » du Président de la République du Zaïre créant la ZOFI.

[16] Discours d'ouverture de la 11ème session extraordinaire du Conseil des ministres de l'Organisation de l'Unité Africaine, Kinshasa, 6 décembre 1976, in « Mobutu Sese Seko, discours, allocution », 1976-1981, tome 1, pp. 52-62.

[17] MUNASINGHE M., *Electric power pricing policy.* World staff working paper, n. 340 (July 1982), Washington D.C.

[18] SPE, *La demande d'énergie dans la Zone d'influence d'Inga (y compris le Shaba).* Internal report (1983).

[19] MROCHEK J.E., HOLMES J.M. and MICHEL J.W., *Role of electricity-intensive industries in the economics of nuclear power,* in « Nuclear energy costs and economic development », IAEA, Vienna (1970), pp. 639-652.

[20] Veziroglu T.N., Van Vorst W.D. and Kelly J.H., *Hydrogen energy progress*, vol. 1, to 4. Proceedings of the 4th World hydrogen energy conference, California, USA (June 1982), Pergamon Press.

[21] Pickett A.P., *Fuel cell power plant for electric utilities and hydrogen.* Int. J. hydrogen energy, vol. 8, n. 8 (1983), pp. 617-622.

[22] Roszkowski T.R. and Suyder N.W., *Present and emerging hydrogen production technology*, in T.N. Veziroglu, W.D. Van Vorst, J.H. Kelly (opus cited), vol. 1 (1982), pp. 47-68.

[23] Vandenborre H. et al, *A survey of a five-year intensive R & D work in Belgium*, in T.N. Veziroglu, W.D. Van Vorst, J.H. Kelly (opus cited), vol. 1 (1982), pp. 107-116.

[24] Vandenborre H., *Projet Elenza: électrolyse de l'eau pour des engrais au Zaïre.* Rapport interne, association SPE-COBELCOM (1983).

[25] Malu, wa Kalenga., and Mpeti N., *Coût spécifique du projet EFI et Elenza.* Rapport interne, SPE (1984).

[26] Peschka W. and Winter C.J., *The secondary energy carriers hydrogen: review of DFV LR-activities*, in T.N. Veziroglu, W.D. Van Vorst, J.H. Kelly (opus cited), vol. 2, pp. 987-998.

[27] Malu, wa Kalenga., *La politique énergétique de la République du Zaïre.* SPE internal report (1982).

[28] Cassette-Carry M., *Peut-on croire aux prévisions énergétiques?* Revue de l'énergie, n. 339 (Nov. 1981), pp. 561-572.

[29] Asher W., *Forecasting: an appraisal for policy-makers and planners.* Johns Hopkins University, Baltimore (1979), pp. 202-203.

[31] Daneke G.A., *Forecasting Alternative energy future: the case of solar energy*, in « Energy Transition: long term perspective », ed. by Lewis Perelman, Westview Press (1981), pp. 147-168.

[32] Malu, wa Kalenga., *Les méthodes de prévision de la demande d'énergie.* PUZ (1970).

[33] Malu, wa Kalenga., *Un Modèle économétrique de l'appréciation de la demande d'énergie par tête au Zaïre.* Revue Zaïroise des Sciences Nucléaires, vol. III, n. 1 (juin 1982), pp. 119-134.

[34] Hoffman L. and Mors M., *Energy demand and structural change in developing nations*, in « Energy and the developing nations », ed. by Peter Auer, Pergamon Press (1980).

[35] Munasinghe M., *Third world energy policies demand management and conservation.* Energy Policy, vol. 11, n. 1 (March 1983), pp. 4-18.

[36] Various publications of the World Bank such as: Follen-Bailey D.C. and Byer T.A., *Energy options and policy issues in developing countries.* World Bank staff working paper n. 350 (August 1979), Washington D.C.

Part II

HOW BIG AND STILL BEAUTIFUL?

Abstract

In the first part of the paper, the characteristics of the Inga hydro-electric project in Zaïre and the problems arising from the implementation of the Inga Master plan were discussed. Some of these problems are related to the large size of the project.

In this second part of the paper, the merits and the constraints related to the "size effect" are discussed in a more systematic way.

It is shown that in the prevailing condition of low demand of energy and general unfavourable economic conditions in developing countries, sound energy system planning requires to balance the "size effect" with the "series effect" in order to improve financial viability of an energy project and to gain in management and technological expertise.

II.1. Introduction

The major decisions concerning Inga hydro-power plants and the HVDC Inga-Shaba transmission line were taken in the sixties and earlier seventies, that is before the oil shock of 1973 and the subsequent inflation and interest rate shocks of the 1970's and earlier 1980's.

For more than 20 years before 1973, electric industry has experienced almost everywhere, in the industrialized as well as in the developing countries, a steady growth in demand exceeding 7 per cent per annum which translates into a 10 years doubling time. This was due to declining real price of electricity, resulting from large and more efficient generation units, high capacity, efficient and more reliable transmission and distribution systems and a general climate of growing economic activity along with an increasing general standard of living. In fact demands of energy forecasts made during this period seldom were as high as the actual growth experienced.

In this context, sound and prudent planning dictates the massive ordering of ever bigger units, taking into account the economy of scale as well as the growing constraints related in part to the regulatory requirements (licensing delays due to safety and environmental concerns) and to the increasing equipment delivery difficulties. In light of the situation up to 1973 and in the absence of any indication of the coming future shocks, another action would have been seen as irresponsible.

Since 1973, the world economy has experienced serious convulsions resulting from the quadrupling of the petroleum prices in 1973-74, followed by an 80 per cent increase in real term during 1979-80.

The industrial market economies went into recession in 1974-75 and since then have been confronted with a "stagflation" phenomena, that is with successive peaks of economic activity occurring at ever higher levels of unemployed and higher inflation, the latter slowing only lately. The end of the 1970's decade saw an "interest-rate shock" following the use of restrictive monetary policies to combat inflation in the leading industrial countries. In the second part of the 1970's decade and in the early 1980's the real prices of major primary products exported by developing countries — adjusted for rising prices of imported manufactures — fell to their lowest level since World War II [1].

To gain some perspective on the extraordinary magnitude of this convulsion one can list the following statistics [2]:

— world trade in fuels increased from $ 29 billions in 1970 to $ 535 billions in 1980;

— the current account deficits of the oil importing developing countries, as a proportion of GNP, doubled from around 2,5 per cent in 1973 to 5 per cent in 1980;

— debt-servicing payments of all developing countries, deflated by their export unit values, rose nearly threefold between 1972 and 1979;

— interest rates, deflated by export prices, rose from 10 per cent in 1979 to 29 per cent in 1981.

Countries and societies have responded to these extraordinary events by some form or other of adjustment. The mode of adjustment varies. At the country level four basic ways (and combination thereof) to respond to external shock exist that have been used by developed as well as developing countries: trade adjustment (export expansion, import substitution), domestic resource mobilization (saving by reduction of consumption), investment slowdown (reduction in the ratio of investment to GNP), additional real external financing.

These adjustment measures seem to have induced at the society level the emergence of new political, socio-economic, and ethical values. Those that find greater expression to-day are: collective individualism, commercial autonomy, return to "basic needs" economies, more atomized community patterns partly due to reduced mobility induced by the oil-shock, conservation and efficiency concerns, environmental concern.

The conservation and efficiency concerns led, on a purely technical base, to a general trend of integration and aggregation of industrial processes which superimposed itself on a general societal dis-aggregation trend.

Some of the adjustments and some of the values may be temporarily depending on the nature and the expected duration of the shock to which they respond. This seems to be the case for example for the "interest rate shock".

On the other hand, increases in oil price which have a large permanent component have induced adjustments in demand and supply that seem to be durable.

On the demand side one witnesses a large drop in consumption level which seems to adjust itself to the amount of the transfer to be made to oil exporters [1].

On the supply side one has a general realignment of the price of energy produced and of other factors at their new higher opportunity cost.

The outlook for the future is in all probability for continuing limitation of growth potential in the energy sector as well as in the overall economy. The rule of thumb is that the economic growth rates would be no more than the sum of the rate of growth of energy savings and the rate of growth of energy supply [3]. From the experience of the last decade this could be calculated to be likely around 3 per cent.

Assuming a 3 to 4 per cent growth rate per annum in GDP and a 1 per cent per annum increase in the efficiency of use of energy, then the growth rate of energy supply will be around 2 to 3 per cent in the future (see table 1).

With a growth rate of 3 per cent per annum of electricity consumption the doubling time is more than twice the doubling time at the pre-1973 rate of growth of electricity (around 7 per cent).

At 7 per cent growth rate per annum and average lead time from ordering to commercial operation of about 6-8 years, which was the case

TABLE 1 - *Growth rate (per cent per annum) for Key indicators.*

Indicator	Countries	1973 1980	1980 1981	1981 1982	1982 1983	1983 1984	1981 1985	1986 1990	1990 1995
G.D.P.	I.A.E.	2,4	1,6	−0,6	2,25	3,5-4	1,5	2,8-3,5	n.a
	Developing countries	4,6	4	2,2	3,9	3-3,5	4,5-5,7	4,5-5,7	n.a
T.P.E.	I.A.E.	0,9	−2,1	−3,5	n.a	n.a	2,7	2,1-2,7	1,7-2,7
T.P.E. / G.D.P.	I.A.E.	−1,5	−3,7	−2,6	n.a	n.a	−1,2	−1,2	−1
T.En.C.	CORECH	(4)	(0,3)	(0)	n.a	n.a	n.a	n.a	n.a
(T.El.C) (a)	World	2,2 (3,7)	2,2 (3,7)	2,2 (3,7)	n.a	n.a	2,6-3,4 (4,2-5,2)	2,6-3,4 (4,2-5,2)	2,6-3,4 (4,2-5,2)
	Indust. countries	1,4 (2,8)	1,4 (2,8)	1,4 (2,8)	n.a	n.a	1,9-2,7 (3,3-4,2)	1,9-2,7 (3,3-4,2)	1,9-2,7 (3,3-4,2)
	Developing countries	4,3 (7,6)	4,3 (7,6)	4,3 (7,6)	n.a	n.a	3,7-4,6 (6,7-7,9)	3,7-4,6 (6,7-7,9)	3,7-4,6 (6,7-7,9)

Symbols: G.D.P.: Gross domestic product
T.En.C.: Total Energy consumption
I.A.E.: International Energy Agency (21 Industrialized Members)
T.P.E.: Total Primary energy
T.El.C.: Total Electricity Consumption
CORECH: European Common Market Countries + (Austria, Switzerland, Sweden, Portugal, Spain)

(a) The numbers in parentheses refer to total electricity consumption.

Sources: Energy balances of O.C.E.D. countries (Paris 1983)
IMF, World Economic Outlook, Washington D.C. (1984)
I.A.E.A., Energy, Electricity and Nuclear Power estimates for the period up to 2.000 (September 1983)
World Bank, World development report, 1981, 1982, 1983, Washington D.C.

for nuclear reactors in the pre-1973 period, the utilities must have "on order" at a given time a total new capacity over the next 10 years equal to about two-thirds of all capacity they have in operation.

At 3 per cent growth rate per annum and the same lead time, the total needed capacity is reduced to about half over the next 10 years.

The question then arises to know if it is still better to order the same big units that were the rule in the pre-1973 period or is it advisable to reduce the unit size to about half and aim for a general decentralized schema within a general interconnected power grid ([1]). In other words: how big and still beautiful?

II.2. Reliability of supply and the "size effect"

The answer to that question has to be made by referring to the main constraints facing utility system planners when selecting output rating for new generation. These constraints are related to three main criteria: unit performance and safety, minimization of construction and generation cost, reliability of customer service.

Depending on the way that these criteria are met differences in unit size and primary energy form (that is nuclear, coal, oil, hydro) will give differences in impact on the utility system operation and system economics. Due to its complexity nuclear energy presents the biggest challenge of the four listed power systems. It is also to-day the best documented power system. On the other hand hydropower is too much site specific to be of value in a discussion of a general nature except in the context of a country where different unit sizes can be easily implemented due to a multitude of choices. Such is the case in Zaïre. Finally there is a general agreement that oil power systems should be phased out either for cost reasons or simply for conservation and self-reliance concerns. We shall therefore concentrate the discussion on the coal ([2]) and nuclear systems by referring to the data available mainly from the developed world. The result can how-

([1]) As far as nuclear reactor is concerned, dual large nuclear units of the reference power of 900-1200 MWe were the standard during the seventies.

([2]) Coal use by industry is anticipated to be lower than previously though because changing coal-oil price differentials have reduced the impetus to convert to coal; continuing energy conservation and more stringent environmental regulation will add a deflationary note. On the other hand, disappointing growth in nuclear power generation will result in increased coal use by utilities.

ever be applied to any mix of power plant systems and primary energy forms. How big, then, and still beautiful in a power grid using mainly nuclear and coal-fired power plants?

For developing countries the question can readily be answered in reference to the reliability of supply criterion which is tied to the availability factor of power plants. Due to the rather low availability factor of thermal power plants, particularly nuclear reactors, (around 60 to 75 per cent), there exists a fundamental limitation to the introduction of large units into the ordinary weak national power grid of the developing countries [7]. The vast majority of these countries have a grid capacity not exceeding 4.000 to 5.000 Mwe with an average of 2.000 MWe.

Due to the lower availability factor of thermal power plants, a utility system must be designed to accept a number of contingencies without unduly disrupting customer service when there is a sudden loss of a generation unit. The loss is reflected by a decrease of system frequency which can be compensated by the self-regulating characteristic inherent in electrical load along with the control action of other generating units if the loss is small.

A one per cent reduction in system frequency will result in an approximate one to two per cent decrease in system load due to the frequency-sensitive nature of the utility load. For large generation losses, the impact is greater and is progressively reflected as follows: voltage and frequency swings, load shedding, and ultimate system break-up or collapse. For a 15 per cent loss of generation, the amount of load shed in order to stop the frequency drop is typically of the order of 67 per cent of the loss generation. To restore the frequency additional generation equal to 33 per cent of the loss generation is necessary.

To sum it up, consideration of voltage and frequency stability and reliability of grid are vital for the choice of the size and location of a plant and its safe and efficient integration into the grid. This conclusion is of a general nature, that is for all primary sources (coal, oil, hydro, nuclear). The only difference is the availability factor which is greater for hydro than for thermal power plant.

A rule of thumb states that the addition of 8 to 10 per cent generating capacity in a single unit to an existing interconnected electricity power grid is the maximum permissible.

Taking into account projection for electricity generation in developing countries, the size of the grid and the possibility (or lack) of a general interconnection across national borders, one comes to the following results [8]:

— the majority of the developing countries could in the foreseeable future not even accommodate a small and medium power reactor (SMPR) of 200 MWe unless cross-boundary interconnections increased the grid capacities;

— a growing number of developing countries would be able to use large generation units (more than 600 MWe); a majority of these could proceed to sizes of 1200 MWe in a decade.

II.3. Power cost and the "size effect"

The second criterion one must take into account is the minimization of the cost of a unit of generated output.

Concerning construction and generating costs, it has been demonstrated that the cost of a unit of generated output at the bus-bar of any primary energy form (coal, oil, nuclear, hydro) decreases with increasing unit rating [5, 6].

One should note, however, from past experience in the construction of thermal power plants in the developed world, the increasing uncertainty with respect to project schedules, regulatory requirements, scope of project, fuel cost and general economic conditions. With the exception of France and Japan, the total project duration from commitment to commercial operation shows, for example, a rapid increase for nuclear and coal-fired plants in all developed countries.

From an average project duration of 5 to 6 years for units entering commercial operation in the late 1960's and earlier 1970's, the lead times for plants committed in the 1980's have increased to 8 to 12 years in most of the big industrialized countries such as U.S.A., Canada, the Federal Republic of Germany. Although the latest nuclear power plants experiencing big lead times are more powerful (unit rating between 900 to 1300 MWe) there does not appear generally a strong direct correlation between lead time and unit rating.

The lead time is more strongly dependent, however, on regulatory and licensing requirements and on general socio-political and economic factors. It also depends on the increasing amount of craft labour, and on engineering and field services. These increases are tied to the rapid rise of unit rating within a generalized absence of standardization except in

France. There is therefore an indirect correlation between increasing lead time and unit rating.

The proportion of operation and maintenance cost on the generating cost also increases with rising unit rating. The impact of general socio-political factors on the production cost increases with rating, reaching 70 per cent for the latest 1200-1300 MWe nuclear power plant [5].

The general trend of increased scope of physical plant, increased engineering analysis design effort, lengthening of project duration and high rates of escalation and interest during construction introduces severe financial constraints. The investment cost of nuclear and coal-fired plants has thus risen in recent years at rates almost comparable with increase in international price of oil (3).

Allowing for interest rate during construction and an average of seven years lead time the cost per KWe has risen fourfold to sixfold in mixed dollars in the U.S.A., Canada, Federal Republic of Germany; that is from about $ 250 in 1969 to around $ 1500 in 1978. For a lead time of 12 to 14 years the 1978 figure becomes $ 2500 per KWe [7].

This is about the cost per MWe estimated by Kraftwork Union of the Federal Republic of Germany for the small reactor in the range 200-400 MWe the company is proposing to prospective buyers in the developing countries [7, 11].

Finally, it is intuitive, although difficult to demonstrate in a general way, that on the basis of total system electricity cost, which includes bus-bar production cost, transmission, distribution and overhead costs, the advantage of size effect can be cancelled out, so that big is not necessarily beautiful in remote parts of a big country such as Zaïre.

II.4. The standardization effect

The indirect correlation between unit size and lead time can be uncoupled by using highly standardized design. As the French experience shows, a high degree of standardization insures shorter lead times, reduces research and development cost, reduces equipment cost through economies of series production.

(3) For a typical 600 MW coal fired plant in the U.S.A., environmental pre-construction activity cost has increased 30 times in 10 years; pollution control equipment cost has increased 10 times; the pre-construction lead time has increased 2,5 times.

Within a given unit power rating (900 MWe in this instance) the lead times have been reduced from 6-7 years for the earlier model to around 5-5,5 years for the latter power plant. The overall benefit shows itself in the form of a 10 to 15 per cent reduction in the cost per unit of generated output (KWh), an increase in quality assurance and availability factor. The latter becomes comparable to those of conventional thermal power plants (around 65-70%). The safety is also enhanced because of a better disponibility of equipment, greater know-how of the design, construction and operation staff. The same results are anticipated for the 1300 MWe reactor series.

These results show that standardization effect can offset a decrease in unit power rating as far as fixed costs are concerned.

All things being equal, it appears that large scale systems based on a large number of small or medium size standard power plants within a general interconnected system can become an acceptable economical proposition.

One can come to the same result by using another approach which is related to the concept of "system replacement energy penalty".

II.5. The system replacement energy penalty

One fact that favors the installation of a larger unit in a power-grid is that utility systems are expected to grow with time. System replacement energy penalty arises when there is a power shortage, since the utility must buy, presumably at higher cost, what it can not produce.

As an example of quantifying the fact that strong growth in the demand of energy requires big unit size in a power system, consider the case of a power grid with a peak load of 8.000 MWe rising at 7 per cent per year with a loss of 5 per cent generation acceptable. The doubling time in this case is about 10 years. To service such a strong demand while reducing the potential negative impact of the loss in a big generating unit on the power system, one can consider the following three alternatives ([4]):

([4]) The fact that utility systems are expected to grow with time at a rapid rate, increases the integrity of the power-grid in case of the loss of a unit. For example, the inadvertent loss of a 950 MWe unit on an 8.000 MWe system represents a 12% loss of generation. If the system grows at 7% per year, in ten years the same loss of unit would represent only a 6% loss of generation, which can be dealt with without too much disruption.

Case 1: build a big unit (950 MWe) now and run it at full output and accept that load will be shed when the unit inadvertently trips off line;

Case 2: build a big unit (950 MWe) now and run it initially at 50% of capacity; increase it in a linear fashion up to the maximum capacity;

Case 3: build a smaller unit (600 MWe), run it at full load and add 350 MWe additional capacity 10 years latter.

Assuming a uniform load factor of 75% for all three cases, it is seen that case 2 amounts initially, all things being equal, to a reduced capacity factor of around 40 per cent.

Let us compare the levelized annual fuel and capacity cost for each option over the expected 30 years lifetime of a power reactor, assuming the evaluating parameters listed in table 2, with 1980 as the committing time.

First alternative:

If we assume that the growth rate of energy demand is at least 7% per year, then by 1990 the 8.000 MW system assumed requires all the energy that could be generated by the 950 MWe running at full output

TABLE 2 - *Assumed evaluating parameters* (cost in U.S. $).

1) Time period	1990-2020 (30 years)
2) Starting time of construction	1980
3) Lead time	10 years
4) Fossil fuel cost	5 ¢/KWh
5) Nuclear plant cost	$ 1.927/KU (950 MW plant in 1990) $ 2.314/KW (600 MW plant in 1990)
6) Nuclear fuel cost	If nuclear fuel costs are estimated at 50 ¢/1.055.000 MJ and the heat rates of 950 MW and 600 MW plants are 110.775 J/KWh, and 111.830 J/KWh respectively, production cost in $ 1.980 are 0,525 ¢/KWh and 0,530 ¢/KWh respectively.
7) Fuel and plant cost escalation	7% year
8) Utility fixed rate charge	12%
9) Present worth interest rate	10% year

Source: See reference [13].

TABLE 3 - *Levelized annual revenue requirements* (in 1990 US $/year; 7% growth rate of energy).

	Case 1	Case 2	Case 3
Capital	$ 227.658.000	$ 227.658.000	$ 224.051.000
Energy	128.516.000	223.808.000	302.191.000
Total	356.174.000	451.466.000	526.242.000

at 75% capacity factor. The other two cases therefore introduce a system replacement energy penalty that can be evaluated using classical discounted cash flow analysis [13, 14].

The result is given in table 3 which compares the levelized revenue requirements of the utility each year for the 3 cases.

The revenue requirements are 48 per cent higher in case 3, and 26 per cent higher in case 2 versus the reference case 1.

Second alternative:

If instead of a 7 per cent growth rate of energy, one has 3 per cent, then the system will require about half the energy needed in the first alternative. Therefore case 1 must be discarded altogether. Case 2 becomes the reference case. In this situation using the same technique it can be shown that the revenue requirements of case 3 are less than 15 per cent higher than the reference case 2. This higher cost of the smaller reactor can be reduced and may be cancelled out by the standardization effect referred in a previous paragraph. Small then becomes beautiful even in developed countries.

II.6. THE FINANCIAL AND MANAGEMENT CHALLENGE

Due to the convulsion experienced by the world economy and the rapid changes in technology and market conditions, it is becoming necessary to devise entirely new strategies of development, aiming among other things at the reduction of the period of transition needed to adapt oneself to unexpected new developments.

The advent of new technologies and the fragmentation of market are drastically altering the requirement of scale. It should be noted at the outset that the "economy of scale" plays to decrease the cost per unit of output only if:

a) the technology is well established and secure; that is, it will not be outperformed quickly by a new one;

b) the market exists for the product and is large enough to warrant large output;

c) the cost and the amount of the financial resources required to set up the project or to switch to a new one from the old are not too high.

Unfortunately these three conditions are becoming hard to meet in to-day's general economic and technological environment, at least in the developing countries. The "oil shock", the "inflation shock" and the "interest rate shock" have contributed with other factors to simultaneously reduce demand, increase cost and create deficit in developing countries [15].

Furthermore by following the same traditional path of rapid urbanisation and industrialization as the developed countries, the developing countries are seeing the absolute cost of their economy and social development increased beyond their borrowing ability and beyond the ability of the internal money market.

To make things worse, evolutionary or incremental change in technology and market conditions is making way increasingly to discontinuity, even a radical one. The switching process is becoming more costly: different and higher skills are often needed, new more complex approaches will have to be taken in production and marketing, new financing at higher cost must be arranged, quality assurance must be guaranteed in spite of the fact that one must start the learning curve from the beginning.

The capital intensity of industrial ventures, traditional as well as high technology ones, is increasing dramatically, making them not only less attractive for employment objectives but also more costly in terms of foreign exchange, particularly when investment incentives induce excessive capital equipment import [16, 17].

Moreover government interventions, direct (i.e. nationalisation and or ownership) and indirect (price control) lead in many instances to a deterioration of product quality, production performance and finally of the financial position of firms.

Lacking in managerial expertise, facing the hazard of ill advised government intervention, very often unable to anticipate, to formulate or to make rapidly enough the precise adjustment necessitated by the rapid technological and market changes in to-day's competitive international environment, burdened with the low productivity of the labor forces, an increasing number of entrepreneurs in developing countries find it advisable to start small in order to benefit fully from the learning curve while spreading the risk of failure [17].

This development strategy minimizes the management burden through approaches that stress decentralisation, selectivity, standardization and incentive. This is essential because of the fact that for the coming decade higher rates of growth will come, according to the World Bank, primarily not from new investment but from more efficient uses of resources [18].

II.7. Conclusion

Smaller power plants than the mammoth of the seventies, distributed in an interconnected power grid seem to be justified in the prevailing uncertainty affecting the still less energy intensive economies of developing countries.

This conclusion is justified by the following important trends:

— the decline in the favourable economics of scale of big central generating plants which must now operate on expensive fuel, within the context of a general slackening of the demand of energy, and which exhibit a rapid escalation in design and construction cost;

— the increase in real cost of oil and gas used to provide heat for building and industrial processes;

— the advent of new modular technologies based on small, distributed prime movers such as fuel cells, pressurized fluidized bed combustion (PFBC), industrial heat pump (closed-cycle and open-cycle system), modular coal gasifiers, and ultimately solar energy;

— the attractiveness of "Dual energy use systems" such as the combined heat and power system using for example PFBC and fuel cells as prime movers;

— the aggregation trend in industrial processes which enhances conservation and efficiency.

The success of this "diffusion strategy", that is the distribution of large numbers of small standard power systems, depends on economic, institutional as well as technological factors. This strategy seems to be appropriate in the prevailing general economic conditions. It seeks to minimize capital requirements and maximize use of investment by a better planning of incremental growth of both power plant capacity and energy distributing system in step with the expansion of the economy and of the community.

It seeks to take advantage of the increased reliability and cost advantage associated with standardization due to multi-plant installation. It permits the progressive building up of alert managers capable of tackling in a more appropriate way large, capital intensive power station projects.

REFERENCES

[1] MITRA P.K., *World Bank research on adjustment to external shocks.* World Bank Research News, vol. 4, n. 3 (1983), pp. 1-15.

[2] World Development Report, 1981, 1982, 1983 issues, World Bank, Washington D.C.

[3] DAGLISH J., *Future energy.* Atom 292 (March 1981), pp. 70-73.

[4] DAVIS W.K., *The evaluation of nuclear power in the U.S.A.*, in « Nuclear power experience », vol. 1, I.A.E.A., Vienna 1983, pp. 49-59.

[5] HELD C.M., *Evolution of size-sealing effects on electricity producing costs during the 1970's*, in « Nuclear Power experience », vol. 2, I.A.E.A., Vienna (1983), pp. 623-633.

[6] BENNELT L.L. and KAROUSAKIS P.M., *Review of nuclear power costs around the world*, in « Nuclear Power experience », vol. 2, I.A.E.A., Vienna (1983), pp. 242-262.

[7] MALU, WA KALENGA., *Global outlook of nuclear power in LDC's in the 1980's.* Paper presented at the « Science advisory committee of the I.A.E.A., 14-15 december 1981; reprinted in « Revue Zaïroise des Sciences Nucléaires », vol. II, n. 1-2 (juin-décembre 1981), pp. 1-4.

[8] Possible additional I.A.E.A. measures to explore the applicability of small and medium sized nuclear Power Plants to developing countries; interoffice memorandum, I.A.E.A. (1983).

[9] *Nuclear Power Reactors in the World.* Reference data series n 2, 1981, 1982, 1983, I.A.E.A.

[10] CARLE R., *Planification et développement du programme nucléaire français*, in « Nuclear Power experience », vol. 1, I.A.E.A. (1983), pp. 182-206.

[11] *Small and medium size nuclear power plants.* Modern Power systems, vol. 1, n. 10 (Nov. 1981), p. 25.

[12] GOUNI L., BIGEARD C., GAUSSOT D. and SAGOT M., *Expérience technique et économique de la production d'énergie nucléaire*, in « Nuclear Power experience », vol. 2, I.A.E.A. (1983), pp. 225-236.

[13] PROPST H.R., *Determining optimum size of a nuclear unit.* National Development (August 1983), pp. 13-18.

[14] HERTMARK D.I., *Techniques for energy project evaluation.* Renewable Energy Review Journal, vol. 5 (Dec. 1983), pp. 64-72.

[15] *International adjustment in the 1980's.* World Bank staff paper n. 485 (August 1981), Washington D.C.

[16] DE VRIES B.A. and BRAKEL W., *Restructuring of manufacturing industries.* World Bank Staff working paper, n. 558, Washington D.C. (1983).

[17] MALU, WA KALENGA., *Is small beautiful in the LDC's energy sectors?*, part. I, Revue Zaïroise des Sciences Nucléaires, vol. 3, n. 2 (1982), pp. 135-146.

[18] World Bank, World Development report 1983, Oxford University Press, Washington D.C. (1983).

TRADITIONAL ENERGY SOURCES IN DEVELOPING COUNTRIES

G.B. MARINI-BETTÒLO
Università di Roma - La Sapienza

I am rather impressed by the presentations and by the program of this meeting which covers almost all the aspects of energy in developing countries.

I am not an expert in energy; I have a certain acquaintance with the problems of developing countries and I should like to draw your attention to some minor aspects of energy use which should not be in my opinion disregarded in making a balance of energy needs.

Beyond the rough and rather incomplete definition of a developing country, which considers a uniform standard for all developing countries, there are great differences [1] not only among them but also within the frame of a single developing country. In effect there are two different realities: *urban areas* with their problems of overpopulation but also with industries and commerce, and the *rural world*.

Rural areas have great problems, due to distances from centres, lack of drinkable water, power and also in many cases of health.

These are the areas where 69% of the population lives (in industrial countries the average is 29%).

I understand that energy supply for rural areas will be considered in this meeting, as well as electrification, use of biogases, and other adapted technologies, like a better use of solar energy for heating etc.

Actually the needs of energy in a village of a tropical country are:

1) the use of energy for preparing food;
2) the energy for heating (or cooling);
3) the energy for transport;
4) the energy for agriculture.

Energy for domestic uses

The energy for domestic use — cooking and heating — is mainly obtained in many countries from the burning of wood.

This means that wood and crop residues are largely used, the use of petrol being difficult and expensive.

In terms of numbers and figures, in the case of Africa it is calculated that 40 kg of firewood per year per person are used; that means, according to the Unesco estimates, that in Africa about the equivalent of 95 million ha are scorched to the ground every year [2] (Mbeche).

Energy needs here face the problems of desertification, at least that of modification of the ecological balances in many developing countries.

I think this is an aspect to examine with great care and even try to suggest some valuable solution in the frame of a village economy. The use of rapid growth of plants producing wood has been suggested as an alternative solution both against desertification and for wood supply. The use of some Leguminosae having the capacity of rapid growth and easily adapted to the different soils and climates has been studied by different international organizations: under study and experiments are *Leucaena leucocephala*, *Albizia falcataria*, *Acacia mangium*. The main requirement for the use of these plants is a rapid growth: *Leucaena* can be used for wood after four years. Thus a reasonable planning may, even in

TABLE 1 - *Tree species for wood production.*

Leg	Acacia confusa	Firewood	30 m^3/ha	Wet subtropic
	Acacia farnesiana	Fuelwood	25 m^3/ha	Dry tropics
	Acacia mangium	Firewood		Moist tropic
	Acacia mearusi	Fuelwood		Moist subtropic
	Acacia nilotica	Firewood	5 m^3/ha	Dry tropics
	Acacia Senegalensis	Firewood	40 m^3/ha	Dry tropics
	Calliandra calothyrsus	Firewood		Moist tropic
	Leucaena diversifolia	Fuelwood		Dry tropics
	Leucaena leucocephala		50 m^3/ha	Dry tropics
	Prosopis tamarugo			Dry tropics
	Albizia falcatana	Fuelwood		Saline soils
	Sesbania grandiflora		22 m^3/ha	Moist tropic

restricted rural areas, prevent deforestation and supply a great deal of fuel wood [3].

The work in this field by the Canadian agency, the International Development Research Centre, is quite important and should he taken in account in energy planning in developing countries. Another source of fuel for domestic use in many developing countries is dried cow dung. This point may be related to what follows.

Energy for transport

The best way for transportation, even with lack of good roads, is always a truck or a jeep, but this is not always possible in the economy of the village and even in some towns.

I have seen a typical example of energy supply and transportation in Ethiopia where Eucalyptus branches and leaves are to be used as fuel and are transported by caravans of dozens of little donkeys.

Donkeys are largely used especially in the mountain area for transportation in Africa (North Africa, Ethiopia etc.) and in South America (Colombia).

But also other animals are used for this purpose, especially species trained for this purpose: the camel in Africa and in Asia, the yak in Asia, the llama in South America.

In India there is an estimate of the existence of 80 million work animals. Their work covers 2/3 of the transportation and 2/3 of the plowing of the agricultural area.

A recent study by Goe and McDowell indicates a number of animal species used for transport indicating also the average load and speed (see table 2) [4].

The same Authors report for the same species also the draught capabilities (table 3).

The use of one or other species depends on the area and the climate, in order that animals that are adapted to climate and environment are used. We may recall the great difficulties in some African countries due to trypanosomiasis of the animals [5].

Power for agriculture

For agriculture, developing countries rely in great part on manual and animal power. FAO data reports that in rural areas of Africa and

TABLE 2 - *Capabilities of various species for pack loads 6 to 8 h per day.*

Type of animals	Weight kg	Speed km/h	Load kg
Horse	500	5,6	60
Mule	500	7,2	65
Ass	200	5,6	54
Camel (Bactuan)	630	4,0	200
Camel (Dromedary)	500	4,0	140
Elephant	2.900	3,5	460
Yak	350	2,8	85
Yak hybrid	500	2,8	120
Buffalo	650	3,0	82
Ox	450	3,5	55
Llama	120	4,5	40

TABLE 3 - *Draught capacity of several species* [6] (Average).

	Mature weight kg	Speed km/h	Tractive effort kgf	Power (1 kw = 1.34 hp)
Horse	500	4,0	50	0,55
Mule	600	4,0	60	0,66
Ass	200	4,0	24	0,27
Ox	450	4,0	45	0,50
Cow	575	3,5	48	0,46
Buffalo	650	3,2	65	0,57
Dromedary	600	4,0	60	0,66
Elephant	2.900	2,0	230	1,27

Asia 85-95 percent of the rural population depends on manual, animal draught power for cultivation and transportation.

In developing countries animal draught power represents a fundamental contribution to the economy of developing countries and to the agricultural production.

FAO evaluation (1980) indicates that the power in agriculture from a survey in 90 developing countries can be attributed for about two thirds to hand labour and 25% to animal draught power, with little difference for the different continents: in Latin America handpower is 56 percent, in Africa 84. Animal power global average is 25%, but in Asia this figure rises to 31%.

The use of machine power generally does not exceed 10% of the power needed.

The cost of the draught animals and associated infrastructures is evaluated by Prof. N.S. Ramaswamy at 100 billion dollars, corresponding to some 400 million animals. They make available 150 million hp.

Planning the substitution of the animal power by machines, the cost is estimated to be of 250 billion dollars for capital equipment and that of the fuel may exceed 5 billion dollars per year.

Although productivity will be largely increased by agricultural mechanization, this goal cannot be foreseen for the moment because of many economic and practical reasons.

In effect independently from the cost of the tractors there may be often problems of maintenance service and space parts which may stop for long periods the use of the machines as I have personally observed in African

Table 4

Draught animals in the world in developing countries

Cattle and Yaks	246	61
Buffalos	60	15
Horses	27	7
Mules	10	3
Donkeys	40	10
Camels	16	4
Llamas	1	

countries. This means also a continuous presence of foreign experts, which is possible only at the level of large cultivations run by companies for the export of the crops, but not in the small village economy. The growth of the number of draught animals in developing countries is therefore expected to double in the next twenty years in order to fulfill the needs of increasing population, although in the same period a large mechanisation effort will be made.

Conclusions

Animal draught power represents an important source of renewable energy. A realistic approach to the betterment of agriculture in developing countries gives high priority in effect to draught animals because the great number (millions) of small properties, below 5 ha, cannot afford an economical use of tractors. Even more lands, e.g., marshes do not permit the use of mechanized systems. This means more credit facilities to farmers but requires also an intelligent planning at regional or national level in order to coordinate this effort in a more global plan for betterment of the animals, the production of meat and milk etc.

Nevertheless animal power in developing countries should anyhow receive more attention than it does. Traditional methods in the use of animals should be improved: first of all using animals of selected race, resistant to climate and to diseases. Second: animal feed should be adequate. A higher yield in available power is obtained in this case — and with some species a return in form of milk and meat.

Animal health problems should be also studied to avoid or reduce parasitic and other diseases which affect animals in the tropics, like trypanosomiasis and ticks and others.

Finally the harnessing, the form of the plough and of the carts or packs should be adequately studied to improve the efficiency of the system.

This means also research in the field which should be carried out in the frame of general guidelines in every region or according to their specific needs by local scientists. The present state of the use of animal manpower is based on an equilibrium of survival in many cases, it is thus necessary to improve the system, without hurting valid traditions. It is important also to consider the transformation towards a better use of animal manpower in terms of economy: as an example, a slight betterment in harness may bring an improvement of 200% in pay-load: better fed animals may give a higher power output, etc.

The present low productivity should be ameliorated with betterment of the breeds, better animal care and nutrition.

The animal power — in my opinion — constitutes a very important aspect of the overall problem of energy even in the present technological century, and this is the reason why I have presented this problem in order that you may consider it as a factor, and not a minor one, in the energy balance of developing countries.

REFERENCES

[1] Marini-Bettòlo G.B., *Scienza, politica e tecnologia.* Ancona, SIPS 1983.

[2] Ombeche O., *Energy needs in Africa.* Int. Conf. on Alternative Energies, Milan, April 1980, p. 109.

[3] *Leucaena Research in Asian-Pacific Region.* IDRC, Ottawa, Canada 1983.

[4] Goe M.R. and McDowell R.E., *Animal traction guidelines to utilization.* Int. Agr. Mimeo 81, Cornell University, Ithaca, N.Y.

[5] Goe M.R., *Current status of research on animal traction.* « World Animal Review », *45*, 2 (1983).

[6] FAO, Report on appropriate use of animal energy, in: Agriculture in Africa and Asia. FAO, Rome 1982.

ENERGY AND RURAL DEVELOPMENT

MOISE MENSAH
International Fund for Agricultural Development, Rome

Whether or not energy will continue to retain the world attention as a serious issue will probably depend more on factors such as safety and prices of the various sources of supply as assessed by the industrialized nations rather than the energy needs of developing countries. Indeed developing countries, including both energy exporting and importing nations consume only 20 per cent of the world commercial energy — oil, natural gas, coal, hydropower and nuclear energy — while fuelwood, charcoal and other traditional fuels such as dung and crop residues are about the unique source of fuel of some two billion people. Most of those two billion people live in rural areas, as small farmers and landless workers. They constitute the population target group for which the International Fund for Agricultural Development (IFAD) was established in 1977. IFAD's main objective is alleviation of rural poverty through increasing food production as well as income-generating activities by the lesser privileged population strata within the rural communities in developing countries.

IFAD's interest in the energy issue stems from a genuine concern as to whether or not energy is a problem within the totality of rural poverty. Most agricultural and rural development projects, including those supported by IFAD, are energy consumers; either directly — e.g. traction power, processing — or indirectly — e.g. fertilizers and pesticides. Therefore, it is important to assess the energy implications of increasing the productivity of the project beneficiaries over the shorter and longer term. With regard to the longer term, due attention must be given to the type of farming system and related living standard which, in the future, are most likely to keep the son and daughter of the small farmer in the rural areas. Such a farming system will certainly be more energy intensive than is the case at present, if aspirations for economic and social progress are to be met. That adds to the energy requirements to achieve the overall agricultural production targets necessary to meet demand due *inter alia* to population increase. The Food and Agriculture Organization of the United Nations (FAO) submits in its Study "Agriculture Towards 2000" that in order to achieve a 3.7 per cent per year increase in food production in developing countries within the period 1980-2000, the technological packages needed will call for a higher degree of mechanization and utilization of inputs (chemicals and irrigation) which would require a five-fold increase in the demand for commercial energy — from 36 million tons of oil equivalent in 1980 to 178 million tons in the year 2000. That represents an annual increase rate of 8.3 per cent. Even assuming an annual food increase rate of only 3.2 per cent, the demand for commercial energy would still grow at 6.9 per cent per year. These figures suggest that while at present agriculture is responsible for less than 5 per cent of the commercial energy bill in developing countries, the dimension of future needs might be such as to raise problems of energy resource allocation between agriculture and rural development on the one hand and the development of other economic sectors on the other.

Another consideration to bear in mind is that some project activities may affect specific sections of IFAD's target group. For example, fire-cured tobacco production may have a negative impact on availability of fuelwood for domestic consumption purposes. The demand created by the tobacco related activities could not only put fuelwood beyond the reach of the rural poor but also add to the workload of women and children who may have to travel much longer distances to fetch the needed fuelwood with, sometimes, far-reaching negative impact on family life.

Having underlined the energy consuming aspects of agriculture, it is appropriate to recall that it is also a source of energy which is particularly under pressure nowadays because of an increasing call on renewable sources of energy. Agricultural land faces often conflicting demands for food and energy production (e.g. ethanol, fuelwood). By allocating land to either food or energy, farmers or landlords may make decisions with far-reaching implications for national economic and social policies. Conversely, Government's policies on commodity prices, environment as well as overall energy strategies may affect positively or negatively the balance between food and energy as far as land use is concerned.

Having due regard to the various points mentioned above, IFAD's approach to the energy issue in relation to rural development is one which recommends the following steps.

A. *Assessment of the macro-level energy factors*

Such an assessment would be made by programming or project identification missions. The main purpose is to understand the energy environment within which any project in a given country would have to take place. Particular attention would be paid to energy conditions which bear directly on agriculture and the rural populations.

The assessment should look into the following points:

1. Total quantity of commercial fuels consumed, with breakdown by fuel.

2. Main forms of energy use in agriculture and rural areas: animal power, human labour; typical domestic fuel consumption patterns; rate of woodfuel depletion; where the responsibility for rural energy planning and provision resides.

3. Fuel imports as a proportion of export earnings or total imports.

4. Reliability of supplies, particularly to rural areas; and means of distribution.

5. Policy-making arrangements (for example, whether an Energy Ministry exists) and their efficacy.

6. Contingency planning and priorities for fuel allocation in the event of energy scarcities; strategic stock-piling.

7. Energy programmes or projects under way or planned, and a rough assessment of them.

8. Availability of reliability of electricity; whether generated by imported or indigenous energy sources; extension of the grid to rural areas.

The purpose of this information is no more than to have a framework within which project identification and formulation could realistically take place. Most projects require reliable supplies of commercial energy. It is a vital part of project planning to make a clear assessment of the likelihood that energy needs will be met. This information will also furnish a basis for considering which aspects, if any, should receive particular attention at later stages in project identification, and design.

B. *Project Area Energy Data*

The objective at this stage would be to obtain a picture of the energy supply and demand patterns and the social context in which they have evolved within the project area. Attention would primarily be directed towards the target group, but it is also important to identify the general framework of energy supply.

The information would be collected under the following headings:

1. Patterns of commercial fuel supply: end-uses; prices; how distributed and sold; problems.

2. Patterns of non-commercial fuel supply: end-uses (these will be mainly cooking); how and where obtained; costs of procurement (primarily labour); rates of replenishment and depletion; other problems.

3. The role of women (or other groups) within fuel collection and use.

4. An assessment of whether energy is a problem within the totality of rural poverty.

5. Changing trends in patterns of subsistence energy supply and use.

Here, the most important information to obtain is whether local people feel there are energy problems and how they think they should be dealt with.

C. *Project Energy Assessment*

The objective in this assessment is to obtain, as part of the total baseline data, a picture of energy use in the activities directly addressed by the project before implementation; to assess the potential impact of fuel constraints and supply interruptions upon the project; to assess the impact of the project upon the existing fuel use pattern; and to ensure that energy is given due consideration within project evaluation. Efforts should be made to obtain:

1. As detailed a description as possible of the specific energy use patterns.

2. Assessment of the fuel requirements of the project itself and how they will be met.

3. Appraisal of the level of security of energy supplies to the project and the short-term and longer-term consequences of a failure of supplies.

4. Examination of the impact of the project upon the energy supplies of the target group and others who might be affected.

In its project financing activities, IFAD has encouraged the use of technologies which have a sustainable demand of energy. To that effect it has supported research on farming systems which will call for low-input technologies including for example zero tillage, improvement of fertilizer efficiency in tropical soils so as to reduce the amount of fertilizer required, etc. IFAD has also financed project components dealing with renewable energy sources such as Biogas, (bearing in mind conflicting demands for crop residues and waste), fuelwood and small-scale hydro-electric generation facilities. It has been paying particular attention to the choice of farm equipment in connection with commercial energy availability and recurrent costs. The Fund is following with considerable interest ongoing experiments in the field of renewable energy usable by the small farmers and landless rural people. For example, activities carried out by the UNEP sponsored Experimental Rural Energy Centre in Sri Lanka (Pattiyapola village), Senegal (Niagawoloff) and the Philippines (Higantangan Island, Dagohoy, Bohol) seem to hold good promises in terms of harnessing locally available sources of renewable energy including wind power, solar energy and anaerobic fermentation of organic wastes. Likewise, ongoing efforts to harness solar energy in Sahelian countries such as Mali, Niger and Upper Volta deserve attention inasmuch as the energy problem is becoming more and more severe in an area where three hundred thousand hectares of agricultural land are being lost to the desert every year.

Against such a background, this workshop on "Energy for Survival and Development" is a most welcome initiative for which I would like to extend to the Pontifical Academy of Sciences and ENEA my warmest congratulations. There is no doubt in my mind that this kind of initiative can go a long way towards enlightening and strengthening the efforts of those scientists, technicians and policy-makers who, around the world, are wrestling to find new and better ways to solve the growing energy problems of the lesser privileged countries and people.

CRISE DE L'ÉNERGIE
CRISE DE LA COOPÉRATION INTERNATIONALE

AMMAR ZEGHBIB
Ministry of Energy
Algeria

Que l'énergie soit un facteur essentiel du développement économique et social, nul n'en disconvient aujourd'hui. Que nous soyons entrés dans une ère où l'énergie sera de plus en plus rare, donc de plus en plus chère, c'est la principale leçon de ce que l'on n'appelle déjà plus la « crise de l'énergie » et qui aura été l'évènement caractéristique de la décennie écoulée.

Parler d'énergie et de coopération internationale n'est pas chose aisée, car après plus d'une décennie de débats et diatribes, l'on court le risque d'être soit redondant, donc futile, soit moralisateur, donc vain.

Notre propos s'attachera — au risque d'ajouter vanité à futilité — à montrer que si étant donné la situation énergétique des pays en développement (P.V.D.), la coopération internationale dans ce domaine est une nécessité, mais il faut éliminer un certain nombre de malentendus relatifs soit à la définition et à l'approche du problème, soit aux moyens et objectifs à assigner à cette coopération.

La situation économique aidant, ces malentendus ont fait qu'à l'heure actuelle l'on assiste plus à une crise de la coopération internationale qu'à une crise de l'énergie proprement dite.

Comment se présente la situation énergétique des pays en développement, quels sont les malentendus qui grèvent le débat sur la coopération énergétique; comment y remédier si l'on veut relancer cette coopération internationale, qui est actuellement au point mort, comme dans des autres domaines des relations économiques internationales, sont les questions que nous allons débattre.

I. La situation énergétique des P.V.D.

Des inégalités croissantes

Examinant, lors du dernier congrès de la conférence mondiale de l'énergie (CME), qui s'est tenu a New-Delhi en septembre 1983, la situation énergétique des P.V.D. à l'horizon 2000/2020, la Table Ronde, consacrée aux « problèmes énergétiques dans les P.V.D. », arrive à la conclusion que « à l'horizon 2000/2020, les *inégalités vont se creuser* sur le plan énergétique, donc sur le plan du développement, non seulement avec le *monde développé*, mais aussi entre les grandes régions du tiers-monde (I) ».

Voilà déjà ce qui est peu rassurant. Il est ajouté: « Bien que cela ne ressorte pas forcément de l'approche régionale, ces inégalités risquent de se creuser également au sein de chaque région du monde en développement ».

« La balance *énergétique positive qui apparaît pour certaines régions en l'an 2000 ne doit pas faire illusion*, car elle suppose la levée des *contraintes de tous ordres susceptibles* de freiner les *échanges inter-régionaux* ».

Le problème est donc bien cerné, la solution avancée. Sans une coopération, non seulement internationale, mais également régionale et inter-régionale, le monde en développement ne saurait surmonter la crise énergétique qui se profile à l'horizon 2000/2020.

Cela d'autant plus que la crise revêt pour ce qui est des P.V.D. un double aspect dans le sens que la crise des énergies fossiles, principalement pétrole, gaz et, dans une mesure moindre, charbon, se double d'une crise des énergies traditionelles ou énergies dites non commerciales (notamment le bois de chauffe), qui souvent constituent les sources principales des populations rurales majoritaires dans ce qu'il est convenu d'appeler le tiers-monde.

Ainsi, pour ne prendre que le continent africain, alors que les énergies commerciales, pétrole et gaz essentiellement, entrent pour près d'un tiers de la consommation totale d'énergie primaire, les énergies dites non commerciales entrent pour les 2/3, le bois entrant pour 80 à 85% de ce total [1].

[1] L'Afrique, excepté l'Afrique du Sud, totalise un peu moins de 1% des réserves mondiales prouvées de charbon, concentrées dans deux pays: Botswana et Zimbabwe. Cfr. *Rapport sur l'Energie en Afrique. Table Ronde sur les problèmes énergétiques des P.V.D.* S/Groupe de travail Afrique sous la coordination de l'U.P.D.E.A.

Si l'on affine un peu plus l'analyse, l'on s'aperçoit que si l'on exclut l'Afrique du Sud, la consommation d'énergie commerciale en Afrique représente avec 78 mtep en 1980 (141 mtep avec l'Afrique du Sud) à peine 2,5% de la consommation mondiale et 10% de la consommation du tiers-monde par respectivement 15% et 11% de la population.

Dans ce total, le pétrole couvre 67,9%, le charbon 7,7%, le gaz 9% et l'hydraulique 15,4%.

La consommation d'énergies dite non commerciales, représenté toujours en 1980, 128 mtep (sous réserve des erreurs habituelles d'estimation pour ces formes difficilement comptabilisables) et (hors l'Afrique du Sud) entre pour 61% dans le total, soit 1/3 de la part qu'elle prend dans la consommation du tiers-monde, 1/10 du monde et seulement 1,5% de celle des pays développés.

Face à ce bilan de consommation, un bilan réserve qui, sans être négligeable, s'avère cependant insuffisant en regard du taux de croissance de la consommation, projète pour l'ensemble du continent 6% en moyenne (8% pour les pays producteurs-exportateurs nets de pétrole) et de la répartition géographique des ressources.

L'Afrique dispose potentiellement de 5% des réserves prouvées de charbon, dont le 4% en Afrique du Sud; de 9% des réserves prouvées de pétrole brut et de condensats; de 10% de celles de gaz naturel; de 30% de celles d'uranium, enfin de 16% du productible hydraulique annuel mobilisable, auquel s'ajoute un « gisement solaire » estimé à 2500-4000 heures d'ensoleillement annuel avec une intensité oscillante entre 130-210 W/m^2 selon les régions.

Ces chiffres cependant ne doivent pas faire impression. La répartition géographique des ressources les plus immédiatement mobilisables, les ressources fossiles, soit celles sur lesquelles reposera nécessairement la croissance économique des pays du continent pour au moins les trois décennies à venir, est très inégale.

90% du pétrole, 95% du gaz sont répartis entre l'Algérie, la Lybie et le Nigéria; 95% du charbon entre l'Afrique du Sud, le Botswana, le Zimbabwe et le Swaziland, l'Afrique du Sud en détenant à elle seule 80%.

Pour ce qui est de l'uranium, en supposant que l'énergie d'origine nucléaire soit amenée à jouer un rôle important en Afrique et dans le monde en développement de façon générale — ce dont on peut légitimement douter au regard des entraves non pas tant techniques et financières que politiques mises par les pays industrialisés au développement de cette source d'énergie — 90% des réserves exploitables sont réparties entre l'Afrique du Sud — qui en détient à elle seule la moitié — le Niger et la Namibie.

D'autre part, et non moins important, les ressources en hydrocarbures actuellement disponibles suffiront à peine à satisfaire les besoins des principaux pays producteurs eux-mêmes si les taux de croissance projetés ~ 8% d'ici l'an 2000 sont maintenus. Nous signalons qu'un pays comme l'Algérie risque d'être importateur de pétrole à l'horizon 2000. C'est un risque également pour un certain nombre d'autres pays du tiers-monde actuellement en équilibre ou même exportateurs. Si le ratio actuel réserve/production continue à décliner — ce que laisse présager le rythme d'activité d'exploration en-dehors des pays de l'OCDE ([2]), comme le souligne une récente analyse du mensuel « Oil & Energy Trends » — ce risque deviendra une triste réalité.

Notre propos n'est pas ici d'établir un bilan énergétique de la région de l'Afrique, encore moins du monde en développement; d'autres orateurs mieux documentés et certainement plus compétents que nous l'auront fait.

Ce que nous voulions illustrer par cette digression en chiffres, c'est la situation énergétique telle qu'elle se présente au monde en développement, car les inégalités et distorsions constatées pour l'Afrique sont également présentes dans les autres régions en développement.

C'est dire aussi l'urgente nécessité d'un programme de coopération internationale.

Dans ce domaine les déceptions sont grandes. Tout le monde s'accorde à dire que sans une relance de la coopération non seulement « nord-sud », mais également de ce que depuis peu l'on appelle « coopération sud-est », la situation ne fera qu'empirer particulièrement pour les pays les moins avancés du monde en développement. Mais l'on ne s'accorde généralement ni sur les moyens pour mettre en oeuvre cette coopération, ni sur le contenu du concept même de coopération internationale. Les malentendus ne font qu'empirer lorsqu'il s'agit de coopération dans le domaine énergétique.

([2]) Cf.: Oil & Energy Trends - février 1984.

La coopération internationale dans le domaine de l'énergie: identifier les obstacles, éliminer les malentendus.

Identifier les obstacles par une franche coopération, éliminer les malentendus qui grèvent le débat énergétique, est chose plus difficile qu'il n'en paraît, l'énergie étant plus que jamais au centre d'intérêts complexes, économiques bien sûr, mais aussi politiques quand ce n'est pas stratégiques.

A l'heure actuelle, quels sont les malentendus et obstacles les plus voyants à une telle coopération?

Ces malentendus sont souvent d'ordre conceptuel, les obstacles d'ordre faussement pratique, et tiennent parfois à des questions aussi essentielles que: quelle énergie pour le tiers-monde? Sur quoi doit porter une coopération énergétique? Qui doit « coopérer »? Et comment?

II. Quelle énergie pour les P.V.D.

La question mérite en effet d'être examinée, car au cours des années, pour ne pas dire des « crises », bien des malentendus se sont faits jour quant à la forme d'énergie dominante à préconiser pour le tiers-monde, ou en tous cas pour les pays en développement non exportateurs d'hydrocarbures. Procédant souvent d'un égoisme inavoué ou d'une mansuétude par trop naïve, l'on s'est, 1973 puis 1979 aidant, empressé à vouloir détourner les pays en développement des hydrocarbures sous prétexte du prix prohibitif de ces derniers et de la pénurie que prévoyaient alors à l'unisson les experts.

L'idée consiste à dire que les hydrocarbures étant trop coûteux à l'importation mais encore plus pour ce qui est de la recherche-développement et ressources financières rares, mieux valait pour les P.V.D. « prendre en quelque sorte un raccourci » et développer les ressources renouvelables, énergies de l'avenir. Cela serait d'autant plus désirable que celles-ci s'adapteraient mieux aux conditions de vie supposées des populations des P.V.D., car décentralisées, relativement simples à maintenir, non polluantes, avec un coût social d'utilisation négligeable, contrairement aux systèmes centralisés qui impliquent souvent un profond bouleversement du mode de vie des populations.

L'idée n'est certes pas infondée, mais encore faut-il qu'elle ne procède ni d'un écologisme naïf ni d'un calcul cyniquement égoiste.

En effet, si les énergies renouvelables (traditionnelles ou nouvelles) sont appelées à jouer un rôle dans l'équilibre énergétique des *pays en développement, encore faut-il*:

1. *Premièrement*

Ne pas exagérer leur place dans le bilan énergétique des P.V.D. (et mondial) à *l'horizon 2000*, ni faire du « wishful thinking », car leur développement ne va pas de soi et nécessite un transfert efficace de technologie. D'autre part, leur acceptation par les populations ne va pas de soi, ni contrairement à ce qu'on laisse trop souvent entendre en extrapolant un peu hâtivement les expériences indiennes et chinoises.

2. *Deuxièmement*

Quel que soit le rythme de développement des énergies nouvelles d'ici l'an 2000/2020, la part qu'elles prendront dans le bilan énergétique du tiers-monde ne saurait dépasser 2-3% en 2000 et 5-7% en 2020, soit 0,3-0,4 GTEP, alors que les énergies fossiles, principalement le pétrole et le gaz naturel, constitueront respectivement 36-30% en 2000 (1,4-0,9 GTEP) et 30-26% en 2020 (2,2-1,2 GTEP) et 10-12% en 2000 (0,3-0,5 GTEP), 14-16% en 2020 (0,2-0,4 GTEP), soit encore à peu près la moitié des besoins; le charbon, le nucléaire tenant une place minime dans ce bilan à l'horizon 2000-2020 (3). 12% pour le tiers-monde hors la Chine et les Indes (400-650 GTEP), 20-22% avec Chine-Indes (1-1,6 GTEP) pour le charbon, 2% en 2000 et 3-5% en 2020 (0,2-0,4 GTEP) pour le nucléaire; l'hydraulique couvrant le reste. C'est dire l'importance du pétrole et du gaz naturel pour l'approvisionnement futur du tiers-monde, sans parler de la période actuelle et de l'intérêt à supprimer les malentendus quant à ce que sera la source d'énergie dominante du tiers-monde à l'horizon 2000-2020.

C'est dire également l'intérêt qu'il y a d'ores et déjà à envisager les meilleurs moyens pour assurer non seulement cet approvisionnement, mais l'approvisionnement global du monde en pétrole et gaz, puisque pour le pétrole seulement, à la demande traditionnelle de l'OCDE, viendra s'ajouter une demande des P.V.D., qui constituera 41-33% en 2000 et 60-50% en 2020, ce qui nous amène à notre seconde interrogation.

(3) Cf. J.R. Frisch - Tiers-monde: 2000-2020: une perspective décentralisée de son évolution énergétique globale et régionale - CME - 1983.

III. Buts et objectifs de la coopération énergétique

Organiser une coopération énergétique, le pétrole et le gaz naturel tenant encore une place primordiale dans le bilan énergétique mondial actuel et une place grandissante dans celui du tiers-monde, revient à concevoir des projets pour un meilleur approvisionnement du monde, y compris des P.V.D., en ces ressources épuisables. Là aussi, faut-il éclaircir les malentendus, car il y en a. Tout d'abord, le malentendu du prix et l'approvisionnement OPEP:

Dans ce domaine, il faut se résigner définitivement à une énergie chère, dont la disponibilité est en diminution. Au rythme d'extraction pétrolière fin 1981, les réserves OPEP en auront pour 32 ans en 1990 et 20 ans en 2000, à moins de découvertes majeures. La situation présente d'apparent surplus ne doit pas faire illusion, car elle ne saurait durer au-delà de 1985-86, la reprise économique aidant. Le pétrole et le gaz seront de plus en plus chers, non seulement à la consommation, mais aussi à la recherche et production.

Aussi faut-il mettre un terme définitif aux faux espoirs d'une énergie bon marché et consacrer les efforts de la coopération internationale à explorer notamment dans la zone OPEP pour accroître la disponibilité en ressources pétrolières et gazières. Il faut aussi accepter de payer un prix rémunérateur aux producteurs si on veut les voir consentir à l'effort d'investissement nécessaire à la mise en valeur, c'est-à-dire la mise à disposition, de ces ressources.

Seul un effort de recherche continue, non discriminatoire, c'est-à-dire non seulement dans les zones OCDE dites sûres politiquement, mais également dans les régions en développement y compris la zone OPEP, qui reste la plus prometteuse, est à même de permettre la transition vers les énergies du futur.

Il faut en effet cesser d'assigner à toute politique énergétique internationale comme but essentiel l'indépendance vis-à-vis de l'OPEP, quelles qu'en soient les conséquences, car si ces conséquences sont déjà financièrement lourdes pour les pays industrialisés (l'exploration hors OPEP coûte plus chère et les probabilités de découvertes sont moindres), elles risquent d'être pénibles pour les P.V.D. Le but à assigner à toute coopération internationale énergétique serait d'accroître l'autosuffisance énergétique des régions en développement, non pas de les couper du flux d'échanges internationaux de l'énergie, car en faisant ainsi, on les coupe des flux d'échanges commerciaux et financiers au risque de les mettre a l'écart de la croissance de l'économie mondiale. Mais qui doit coopérer? Répondre à cette question est primordial si l'on veut une coopération efficace et non un simple échange de souhaits.

IV. Les partenaires de la coopération énergétique internationale

Parmi les gouvernements et les entreprises, qui doit avoir l'initiative? Et si ce sont les deux, comment éviter le sacrifice des intérêts des uns au détriment des autres? Même si forcément on doit reconnaître ici que le terme « coopération » est plus du langage des gouvernements que de celui des conseils d'administration, les entreprises multinationales ont un rôle important à jouer, et il est bien difficile sans elles d'agir dans le sens souhaité.

Dans les activités de recherche, exploration, développement, transfert de technologie, mobilisation des ressources financières, les multinationales jouent un rôle irremplaçable à l'heure actuelle, tout comme entreprises nationales des P.V.D. les plus avancés dans ce domaine.

Il s'agit donc d'imaginer des formules pour concilier les soucis légitimes de profit de ces entreprises avec les intérêts souvent supérieurs des Etats. A défaut de telles formules, la voie de la coopération aura du mal à s'imposer.

Il suffit pour s'en convaincre de rappeler les péripéties des accords gaziers passés par l'Algérie avec la France et l'Italie, où les compagnies gazières de ces pays ont longuement tergiversé avant de consentir à des accords considérés par leurs gouvernements même comme des exemples de ce que devrait être une coopération nord-sud bien comprise. Cela ne nous semble ni fortuit, ni dû à une particulière malice des entreprises concernées, mais reflète la difficulté bien réelle qu'il y a à trouver un équilibre entre les préoccupations à court terme de profit, raison d'être de ces entreprises, et les exigences d'une coopération nord-sud qui soit autre chose que la perpétuation sous d'autres formes d'un rapport inégalitaire P.V.D./pays industrialisés.

Si dans ce cas précis les gouvernements et les entreprises concernés ont trouvé la solution d'équilibre, c'est qu'ils ont su faire preuve d'imagination et de hauteur de vue et placer leurs rapports dans une perspective dynamique, et les entreprises, tout comme les économies françaises et italiennes, recueillent déjà les fruits de cette sage conception.

Cet exemple pourrait sans difficulté être étendu au commerce des autres matières premières exportées par les P.V.D. sans vouloir sombrer dans un optimisme de bon aloi. Il nous semble qu'avec un minimum de bonne volonté et d'imagination de la part des gouvernements, des agents économiques et de nombreuses organisations internationales multilatérales — car celles-ci sont très certainement des partenaires non négligeables de la coopération internationale — beaucoup de contraintes qui reposent sur le développement énergétique, donc sur le développement tout court, des P.V.D. pourraient être éliminées; principalement la contrainte financière.

V. Les contraintes financières

Beaucoup de choses ont été dites et écrites sur la question (4), un certain nombre de solutions avancées, les dernières l'ayant été par une organisation internationale aussi peu suspecte de philantropie que la Banque Mondiale. Rappelons seulement brièvement les termes du problème. Une moyenne annuelle de $ 130 G (5) est nécessaire pour la décennie 1982-1992, dont la moitié au moins en devises, soit $ 64 G, alors que le volume attendu des flux d'origine externe n'excède pas $ 25 G durant la même période (6). Sans entrer dans le détail de l'individualisation des besoins par secteur, le fossé entre besoins et disponibilités est énorme et risque de s'élargir si la crise de confiance actuelle persistait.

Voilà donc bien un domaine privilégié de conjugaison des efforts des gouvernements, des organisations financières multilatérales (et bilatérales) et des entreprises tant bancaires qu'énergétiques, particulièrement les entreprises internationales pétrolières et gazières. Tout d'abord, les gouvernements du nord devraient au plus vite souscrire à la Constitution de la « Filiale Energie » de la Banque Mondiale, tout en accroissant le volume des flux en direction des P.V.D., que ce soit par le canal bilatéral ou les divers canaux multilatéraux, en premier lieu l'A.I.D.

Les gouvernements des P.V.D. eux-mêmes devraient accroître leurs

(4) Voir notamment Y. Rovani D.C. Rao: « Financement des investissements dans le secteur de l'énergie dans les P.V.D. » CME 1983 — et World Bank — « Energy In Developing Countries » 1980 et « The Energy Transition In Developing Countries » 1983.

(5) Dollars 1982.

(6) Cf. Rovani - Rao - World Bank.

efforts pour créer des flux inter-P.V.D. crédibles, car des potentialités existent.

Enfin, les entreprises internationales devraient « déployer une plus large part de leurs énormes capacités financières et techniques dans les P.V.D. (7), ce qui suppose un changement de stratégie de la part de ces dernières et une adhésion aux objectifs de coopération, ce qu'il faut reconnaître, relève encore de l'utopie.

V. Quelques souhaits en guise de conclusion

Il est bien difficile, lorsque l'on traite de coopération internationale, de conclure autrement que par des souhaits, malgré la promesse faite de ne pas en faire.

Le premier souhait serait que les gouvernements du Nord réalisent que nous vivons dans un monde interdépendant et que cette interdépendance à ce jour les a favorisés et qu'il est juste que les P.V.D. aient leur part de prospérité. Ce faisant, qu'ils réalisent qu'il n'est plus temps de monologuer sur le développement, mais temps encore de négocier un nouvel ordre économique à même de garantir le développement des P.V.D. et donc de porter à terme leur propre prospérité.

Plus concrètement, assurer l'avenir énergétique des P.V.D., et pourtant du monde, passe par une redéfinition des stratégies et priorités énergétiques, par un transfert véritable de technologie en aménageant les conditions de ce transfert, y compris pour l'énergie nucléaire, par un rééquilibrage des termes de l'échange des matières premières. Le problème de l'énergie est global; seul un prix réellement rémunérateur des investissements conséquents équitablement partagés entre producteur et consommateur, est à même de permettre la mise en valeur de ressources.

Autre souhait, mais qui s'apparente au voeux pieux, ne plus considérer l'énergie du simple point de vue géo-stratégique, mais se faire à l'idée d'une énergie chère (et peut-être s'en féliciter).

Pour les P.V.D. eux-mêmes, prendre conscience des problèmes, les poser correctement, intégrer l'énergie dans les plans nationaux de développement, gérer correctement ce qui existe, voilà des souhaits qui ne nous semblent pas trop difficiles à réaliser.

(7) Y. Rovani - Al Rao.

Enfin, pour les organisations internationales, prendre la mesure réelle des besoins et des difficultés, avoir le souci de l'efficacité.

Restent les entreprises internationales — savoir arbitrer correctement entre le profit à court terme et leur intérêt à long terme, mieux évaluer les risques de l'abstention, voilà qui relève de leurs obligations quotidiennes.

Mais il est vrai qu'il est de la nature de certains souhaits simples de ne jamais se réaliser.

CONCLUSIONS AND RECOMMENDATIONS

1. Introduction

1.1 - The poverty in which over half of mankind lives and the persisting gap between the rich and the poor is not only a human tragedy, it is one of the greatest problems of our time. It is, in its daily manifestations, an economic problem, and in its essence, a moral problem relating to the right to human dignity on the part of the poor. We believe it puts in question the survival of the world, involving the inheritance to be passed on to future generations. A problem from which the rich countries cannot isolate themselves.

1.2 - Underdevelopment and the contrast between life styles of industrial and developing countries are a major underlying cause of economic, political and military tension and crisis. In such a climate it is easy to predict that difficulties and obstacles in the way of solving survival and development problems will flourish and further aggravate hostility rooted in other factors.

1.3 - Indeed this situation is perhaps most strikingly reflected in the vast amount of resources: financial, scientific, technological, industrial, now devoted to armaments. This drain has major implications. It critically reduces the flow of these resources, so essential to development; it impedes international cooperation and keeps it from growing into true partnership.

1.4 - The gap between rich and poor countries has its parallel within countries, especially within the poor ones where a strong middle class has not as yet developed and where small élites, with products and consumption typical of technologically advanced industrial societies, live surrounded by a sea of poverty. Given the spread of information through television and the other mass-media, the poor majority have daily before their eyes the living model of what is possible with developement, yet which cannot for them be reached in practice. This compartmentalisation is unacceptable. It ignores the fundamental interdependence of rich and poor countries and rich and poor people. It can only lead to increasing discontent as well as inefficient use of effort and resources.

1.5 - Once we have understood the implications of the issues, it becomes obvious that any solution demands a long term approach involving a positive trade-off versus short-term and narrow minded interests. It also requires cooperation between the rich and the poor, increasing interaction between North and South, within the South itself and, most importantly, general recognition of the real significance of this crucial insight.

2. The Role of Energy

2.1 - In the condition of underdevelopment everything is scarce: food, shelter, clothing, medical services, education. So is energy, and indispensable and pervasive ingredient of almost all other essentials for living and a precondition for widening people's options — one way of describing progress. Because of its sudden, steep increase in price over the past decade, energy has justly attracted especial attention. Nonetheless, one must keep in mind that lack of energy is only one, albeit important, aspect of underdevelopment and poverty. It is a consequence — not a cause — of poverty, though its scarcity in turn contributes to difficulties and impedes development. Moreover, most developing countries are experiencing high population growth rates, a factor which adds to energy demand whilst keeping the per capita gap between rich and poor countries from narrowing.

2.2 - Energy problems are many-sided, involving scientific, technical, managerial, as well as political, economic, social, cultural and ethical factors. To look exclusively at the economic aspects, generally the most pressing, leads to a faulty perception of reality and in turn to mistaken policies.

2.3 - There is great diversity among developing countries, and among different income groups and different regions within each country. Generalisations have their usefulness as first approximations, but remedies must be tailored to fit specifics. That is to say, there is no generally valid solution, or set of measures, in the energy field. Plans and projects can be successful only if they are addressed to the solution of specific problems.

2.4 - There is a widespread lack of solid, detailed, tested information on energy use, let alone needs, within developing countries. This is particularly true in relation to non-commercial fuels, such as the fuel-wood which is estimated to fill more than half the energy demand in many developing countries. Thus, one must regard with reservation any claims to precision put forward for comprehensive information, or all-embracing assertions made in the absence of reliable data.

2.5 - As a result of inadequate knowledge, it is difficult as a rule to assess energy needs for development, or to evaluate the most suitable forms in which energy may be supplied. Effective energy planning thus becomes a complex and difficult endeavour. This is not to say, however, that efforts aiming at the setting up of energy planning systems in developing countries should be neglected.

2.6 - In many developing countries, urbanisation is accelerating rapidly. This raises the demand for commercial fuels, many of which are usually imported. The cost of these imports, especially of oil, constitutes a serious economic burden to many developing countries. For the majority it slows economic growth, particularly when it is coupled with a debt service burden, that at the prevailing high interest rates requires continuing large foreign exchange outlays or, if obtainable, additional borrowing. The latter of course only tightens the vicious circle: higher debts — larger borrowings — slower or no growth.

2.7 - The urgency of short-term needs and problems (heavy debt burden; oil import costs; economic recession; unemployment, and others) cause long-term energy choice to be neglected. Prominent among these are prevention of deforestation; the search for alternatives to oil; the production and utilisation of natural gas; the use of renewable energy sources; the indigenous exploitation and/or conversion of coal; the modification of the country's transport system; a transition toward greater stress on energy-saving, etc.

2.8 - Energy is scarse in many developing countries. At the same time, what there is is very often used inefficiently, largely because plant and equipment used are old, often poorly maintained, and not designed originally to be energy-conserving. Thus, the potential for energy conservation, that is to say greater efficiency, is very large, for both exhaustible and renewable energy source. There is equally much room for a more efficient management of energy systems, all the way through from assessment of needs to putting into practice new initiatives.

2.9 - While the raising of consumer energy prices to the level of costs is a difficult matter for government even in the industrial world it should be realised that it is many times more so in developing countries. Even though the merit of market pricing may be recognised, the economic and social impact on consumers must be taken into account in the formation of energy policy.

2.10 - Regional cooperation amongst developing countries, often referred to as "South-South" cooperation, can be higbly effective not only for research and development, but for energy trade and the exploitation of energy sources, particularly in border regions (an example is hydro), or in instances in which one country's demand is too low efficiently to sustain a given energy facility.

2.11 - Development strategies often include plans for the establishment of energy-intensive industries, such as primary metals, chemicals, cement, either to substitute imports, or to exploit local natural resources for exports. The upheaval in energy costs has made it incumbent on developing countries to re-assess such plans so as to determine whether sufficient benefits can still he reaped.

2.12 - In many LDCs industries, transport and the more affluent segments of society dominate the demand for commercial fuels and electricity, and this leads to higher oil imports. The poorer strata still depend largely on non-commercial fuel, such as wood, dung, crop residues, etc., the dependence on which is creating increasing problems.

2.13 - Technical and managerial skills are inadequate and poorly distributed in most developing countries. This deficiency acts as a strong brake on energy planning and practices which could improve the utilization and management of energy.

3. Source of Energy

3.1 - Many developing countries have the geological potential for the eventual discovery of oil and/or natural gas resources. At the same time, however, investment to discover and exploit these occurrences is lagging. There is substantial controversy over the reasons for this situation, except that political conditions seem to have decreased in importance as an inhibiting factor. Few oil-importing developing countries have the capital to invest in exploration, and so reliance is placed on private, foreign risk capital and on international lending agencies, including the World Bank. International oil companies stress the importance of fulfilling on contracts once stipulated, and point out that tax régimes must be such as to make investment both attractive and safe. Developing countries expect, in their turn, to exact the highest return from potential investors for the exploitation of what they consider to be their national patrimony. Also, in view of the low odds on discovering really large fields, major oil companies are usually only mildly interested in exploration, while the host country looks at all future discoveries in terms of their relevance to its domestic needs.

3.2 - Sudden and violent changes in the price and availability of oil can have unsettling effects on both consumer and producer countries. While oil-importing developing countries are hit by rising costs which aggravate poverty and slow down development, oil-producing LDCs, as events in the recent past have demonstrated, can face social and political tension resulting from the sudden arrival of oil weath, especially when such changes sharply accentuate an already unequal distribution of income. Conversely, major reductions in national income due to variations in price and/or export volume, create problems for the implementation of development plans. There is little doubt, however, that the local production of oil and gas is one key to development, and that careful planning can alleviate social problems.

3.3 - Natural gas, although it is a relatively recent energy source even in the industrial countries, can be regarded along with oil as a main source for development. Most developing countries at present lack the necessary infrastructure to transport, distribute and use natural gas. On the supply side, more stress has to be put on exploitation efforts, which have been focussed on oil as, in contrast to natural gas, oil is more readily exportable. Natural gas can replace oil in many uses and even small fields can be significant in terms of local markets. There is no reason why exploration and development of gas fields in developing countries cannot be pursued with the same logic and determination applied for oil.

3.4 - Coal is one of the major sources likely to replace oil in many developing countries in the foreseeable future. It is not, as such, an alternative to oil in many sectors and uses, such as transport; however, it is an alternative in other sectors, such as process heat and electricity generation. Some developing countries have significant coal reserves, and certain of these could produce a high-quality coal, with low sulphur content, which would be easily saleable on the international coal market. But few of these coal reserves have been exploited to date. Nor could exploitation be expected to happen either rapidly or generally, as coal, whether imported or produced domestically, calls for a massive cooperative effort both nationally and internationally, between industrialised and developing countries. The urgency to undertake that effort is great.

3.5 - The greater diffusion of coal use require substantial investment, in order to overcome technical and financial problems related to the lack of mining and transportation facilities, including railways, roads, and ports; the absence of conversion projects to switch to coal from oil the existing power plants and other oil burning facilities; the need to acquire the technical know-how to handle the disposal and/or the utilisation of coal ashes, and to select and operate whatever pollution abatement equipment is required.

3.6 - Electricity has long been regarded as the most attractive and "modern" of all energy sources, but its spread in developing countries is still inadequate. Obstacles to this are the high initial investment required; the need for transportation and distribution installations plus the consumer equipment to utilise electric power; and the need for a large and sufficiently concentrated network of users so as to contain unit costs. Electricity can be a catalyst for development, in the sense of permitting rapid increases in living standards — including education, health, safety — and in productivity in both agriculture and industry. Governments, therefore, have long assumed the considerable responsibility for electrification, and for tbe taking of electricity to rural areas where it would otherwise not arrive because of excessive costs.

3.7 - Rural electrification represents a major element in energy strategy by developing countries; but it is not a panacea. IIn fact, unless it forms part of an integrated approach toward rural development and goes hand in hand with the provision of a complex of other inputs for development, it is bound to disappoint both its advocates and its intended beneficiaries.

3.8 - There exists a widespread assumption that rural electrification will make country life sufficiently attractive to contain migration towards urban areas. This may well be true in the long term, but it can also be argued that the opposite can happen. That is, having experienced the advantages of an "electrified" life, the younger people especially may be motivated to look for more of the same in towns and cities. Although the latter preoccupation should not be a reason for slowing down the rural electrification process, its implications should be assessed in order to establish policies to deal with them.

3.9 - There are several primary sources for centralised systems of energy production, alternative to oil. Whenever possible, priority should be given to local resources such as hydro (both large and small units), coal, natural gas and geothermal. Nuclear energy too could prove an important medium- and long-term option.

3.10 - In the exploitation of hydro potential it is necessary to develop appropriate planning, to match the size of the installation and the demand for electricity. Very large installations require solid firm commitments by big customers before construction, lest they become financial loss for the country in which they are located. The utilisation of small hydroplants, on the other hand, offers to many countries interesting possibilities for development, especially for rural electrification schemes.

3.11 - The development of nuclear reactors smaller in size than those now being built for use in industrial countries is seen by some experts as a viable solution for developing countries. This is, however, a hotly debated issue, in view of the diseconomies of scaling-down our present large nuclear stations, and the lack of recent experience on the safety of reactors of this size.

3.12 - Disregarding the size issue, there are several problems that the proponents of nuclear energy for LDCs have to face. These are related not only to the huge investment required, with relatively long payback times and the consequent necessity to resort in most cases to foreign financing; even more important is the local availability of trained manpower, of efficient and well interlinked infrastructures (government, industry, safety and regulatory agencies) in order to cope with the organisational and management complexity of nuclear power. Furthermore, the signing of non-proliferation treaties by developing countries should be encouraged and the use of nuclear energy for peaceful purposes linked, as it should be whenever nuclear power is esploited, with the acceptance of IAEA safeguards on all nuclear installations.

3.13 - It is often said that roughly half the world's population derives its energy from biomass. Whether or not this is the best estimate matters less than the fact that enormous numbers of people largely in rural areas have in fact to rely for their energy needs on fuelwood, crop residues and dung, with dire consequences for the preservation of forests and for agricultural productivity. The situation is especially grave for fuelwood, which is getting increasingly scarce, so that it takes greater and greater efforts largely on the part of the women-folk to gather it. These are costs which do not appear in any statistical compilation, but which cannot but impede economic and social progress. The fuelwood problem is complex, affecting adversely the forest régime and those involved in collecting wood, and it is posing the problem of ever-increasing energy scarcity for rural consumers.

3.14 - Renewable energy sources besides fuelwood, — other biomass, wind, solar energy — seem to have limited possibilities of making a major contribution to the energy needs of LDCs over the immediate future. There are a number of reason for this. Such sources require considerable individual initiative, on both the supply and demand side. Their technologies, even though simple, must be handled by their users, to make and to repair the plant. In some cases, these technologies are still in the development stage. Unit costs are usually higher than those of conventional sources. Nevertheless, the development of these energy sources via greater research and development efforts, publicisation, and demonstration must be pursued in both industrialised and developing countries given their vast long-term potential.

3.15 - The numerous draught animals in developing countries contribute significantly to the needs of agriculture and transportation, and constitute an asset to these countries. A drive to replace these animals with motor vehicles should be evaluated with extreme care: it would mean the elimination of a major source of energy, which is both reliable and simple, to which its users have long been accustomed. On a national scale such a drive would cause large financial strains both for capital investment and increased oil requirements.

4. Recommendations

General

4.0 - The following recommendations have been drawn from above consideration: they are specifically addressed to the governments of developing countries, as well as to those of industrial nations; to international organisations; to energy companies; to centres of research and education, and to energy consumers. We have not come to the conclusion that there has been no progress. Indeed, there has been. Developing countries have increasingly realised that the energy problem needs to be taken seriously into account by governments. In some countries, subsidies have been increased, energy management programmes have been established, the acquisition of skills and knowledge from outside sources is under way, and in several countries there has been increased receptiveness to foreign investment for the development of domestic resources. In parallel, the industrialised countries have put in motion programmes to contain their own energy consumption. They have increasingly used multinational lending agencies to assist energy development and management in developing countries, even in oil and gas sectors where action had been quite limited in earlier years. The industrial world is paying increasing attention to the practical meaning of interdependence.

In extending these Recommendations, we kept in the forefront of our minds the great importance of agriculture to most developing countries. Agriculture, in fact, represents for many of them the main production system around which the life of the majority of people is organised. Greater development of agriculture is an imperative so as to reduce and then overcome malnutrition and starvation, which afflict too many people in the world. Industrial countries must do all they can to help LDCs build modern and efficient agricultural systems, as the basis for all further development.

Energy has an important part to play in foresting development, not only as such but also as a component in fertilizers and pesticides, for transportation and distribution, electricity supply. If the report emphasises the rural electrification issue, this is hecause the role of governments here is perhaps most obvious, and the chances of error greatest, but other facets of agriculture should not be ignored.

Two other problems besides energy should also constantly be kept present as they have a marked effect on development and cooperation between industrialised and developing countries. The first is the rapid pace of population growth, absorbing much of the benefits of higher investment, improved productivity and technology. The second is continued rearmament which, even if catastrophes can be avoided, drains the world, including the Third World, of scarce financial, scientific and managerial resources. Both tbese issues give an additional sense of urgency to the needs that we have addressed in the more limited area of energy for survival and development.

4.1 - Energy planning is important but is not a target in itself. It must be considered as a continuous activity, integrated with wider economic and social development plans.

4.2 - This activity must basically be the responsibility of nationals of the countries involved. Assistance from outside experts can be helpful, provided a country's specific situation — including its cultural and social characteristics — is taken into account.

4.3 - Building up energy self-sufficiency in developing countries is in most cases a long-term goal. It minimises import dependence and foreign exchange needs, strengtbens supply security, provides employment opportunities, and favours the development of those energy sources most suited to local conditions, thus avoiding the imposition of ways of life alien to the country and its people. At the same time, care must be taken not to make self-sufficiency an overriding goal, regardless of cost. This could be a bad short-term bargain.

4.4 - The investment capable of ensuring an acceptable energy supply to the developing countries is so enormous a sum that the actual level of public and private concern dedicated to it is wholly inadequate. While the World Bank has aggressively moved into supplying both funds and know-how for the development of the energy sector, it would be useful further to raise the level of financing, to set up a special section in the World Bank for energy activities, and also to mobilise additional aid from other multinational and national development agencies. Private investment in increasing national energy production needs to be greatly expanded, especially for oil, natural gas and coal. Special efforts need to be made by LDC governments to create a favourable cost-reward structure, including profit- and production-sharing, cost recovery, and investment incentives, especially concerning taxes. At the same time, foreign companies should attempt to adapt their policies and operations to the needs and special conditions of those developing countries which have not been significant producers in the past.

4.5 - Technology transfer, training and education aimed at the development of local manpower capabilities are of vital importance. It is necessary, however, to move away from the idea of "transfer" or "access", towards one of partnership. As a first step, joint project teams (including experts in technical, sociocultural, and economic problems from industrial and developing countries) should be formed to study this problem in specific instances. Joint pioneer projects, based on a real partnership between industrial countries and receptive, action-oriented local teams should also be launched, based whenever possible on the use of locally available resources and using equipment that can be maintained and possibly manufactured locally, equipment which is of a capital-intensity. Throughout the human element needs to be emphasised.

Technology transfer must be first of all a transfer of knowledge and skills if an efficient pool of leaders and operators is to be built up, and this goes for engineers, technicians, economists, managers, etc. Joint efforts by university and research organisations in both developing and developed countries should always be pursued in a spiriti of active partnership. These include, but are not limited to, exchange programmes, hosting of trainees, and a more efficient flow of information.

4.6 - Conservation is typically a convenient and often quick way of coping with energy problems. Developing countries need to make conservation a top priority, while industrial countries must strive to share their own experience here with the developing countries. Technology has a major role in energy conservation. Therefore, greater efforts should be made to promote applied research activities in developing countries, so that they may develop the specialised human resources they need, and be able to study — and solve — the particular problems they face.

4.7 - Partnership should not be limited to cooperation between industrial and developing countries. There is presented to us a great opportunity with "South-South" cooperation. This should be accentuated so as to diffuse knowledge and experience among countries having similar characteristics and problems. There are already a number of such initiatives in different parts of the world. Energy concerns should be made part of their agenda.

4.8 - Excessive differences in the distribution of wealth and energy use, both between rural and urban areas and within each of them, give rise to difficult economic, social and political issues. Different sectors of the population exert pressures on different forms of energy. Apart from generating more information here, policies must be developed whicb are addressed to this problem and which, in particular, are designed to assist those at the bottom end of the income range.

4.9 - Energy planning cannot go far without information and assessment of needs. This is a field in which international agencies can be, and actually have been, helpful. Increased emphasis should be placed on early completion of needs-assessment studies and analyses, as well as on continuous improvement of information especially with regard to non-commercial sources and uses of energy.

4.10 - Both demand and supply decisions are greatly influenced by prices. Artificially low energy prices will encourage consumption, discourage production, and distort the relative development of energy sources and technologies. While governments everywhere are tempted to keep prices below levels set by the market, this is especially true in developing countries faced with large numbers of very poor consumers. Nonetheless, governments must at all times try to allow prices to reflect actual or expected cost — to an extent compatible with the maintenance of social and political harmony.

4.11 - Migration represents a major problem in some developing countries. One form of migration is internal, from rural to urban areas; another is external, from one country to another. Migration embraces mobility of people in search of employment, but may also be caused by attemps to escape from conflict and violence. The ensuing instability of population creates serious problems for energy planning. Policies designed to manage both types of migration in an effort to improve the labour distribution and the living conditions in developing countries may well in addition contribute to ease the energy problem. One should not overlook, however, that increased availability of energy in rural areas could reduce the need for migration.

Specific

4.12 - Since oil and gas will remain important energy sources for many years to come, it is important to encourage exploration and development of hydrocarbons, especially in countries which now depend heavily on oil imports. A programme to identify the conditions which now hinder exploration is an urgent need, in order that remedial action may be taken. Many factors are involved. These include the government of developing countries and the local enterprises they have set up; the governments of industrial countries, as well as groupings of such countries; the international oil companies, together with prospecting, engineering and other specialized firms. All parties must be encouraged to establish terms and conditions that will permit local production to expand. International lending and development agencies are urged to continue to widen their role as catalysts in this process.

4.13 - Coal exists in significant quantities in many developing countries. It does however require an elaborate infrastructure, which may take a long time to put into place. Developing countries are urged to give prompt and serious consideration to this matter. Given the substantial initial investment in production, transportation and use, both planning and financial assistance from abroad should be made available to overcome not so much the technological as the financial and institutional obstacles.

4.14 - Given the importance of electricity as a flexible high-quality energy vector, priority must be given to enhance electricity production in developing countries. Local resources, whenever available, should be considered first, in particular hydro. The size of electricity-generating plants should be planned so as to match the pattern of evolving regional demand.

4.15 - In countries lacking indigenous energy sources for electricity, the possibility of building nuclear power plants should be seriously considered, especially where it is possible to build up the requisite high technical, managerial, and organisational skills within industry, the utilities and the public administration. At the same time, adequate regulations and operating procedures must be adopted to guarantee that peaceful uses of nuclear power are pursued with respect for safety considerations and in the full respect of non-proliferation safeguards.

4.16 - Renewable energy sources, in particular firewood, are bound to continue to supply a large, if not the major, portion of energy demand in many of the less developed countries. In this context, forests must be protected to fulfil their many functions, of which provision of energy is only one. But time is not on our side in safeguarding the forests in those parts of the world where firewood demand is most insistent and uncontrolled. A multifaceted action programme is urgently needed, consisting of: a) the provision of alternative energy sources; b) schemes to ensure the use of firewood more efficiently; c) the search for ways to increase the supply of firewood through innovative schemes involving both new species of trees and new social and organisational arrangements, on the individual or community level.

4.17 - There is a great need to develop a realistic perspective for a more major role for solar energy to play in developing countries. Misallocation and excessive dispersion of scarce resources should be avoided. Developing countries should look for those special occasions in which new technological development in such areas as photovoltaics, biogas or wind can play a critical role in raising standards of living, particularly in rural areas. Some of these technologies can help provide the minimal quantities of electricity, instrumental in supporting in villages a television set to provide basic education, a refrigerator to cool vaccines or perishable drugs and so forth. Solar and wind energy can help to increase agriculture production by pumping and desalination of water, and drying and refrigeration of crops. Matching the characteristics of emerging technologies with specific applications is a high priority.

4.18 - The end of constant oil price increases from the beginning of the 1980's has led to the abandonment of much energy research and development. Research especially in renewable resources has slowed down in several industrial countries. At the same time, very few of the developing countries have the financial and technological capacity for carrying on an adequate R&D programme. It is therefore of vital importance that the industrial countries continue their R&D without hesitation preferably in close partnership with developing countries. This long-term need must not be allowed to languish.

4.19 - In the important drive to exploit domestic energy resources, all feasible care must be taken to safeguard environmental values. This is of especial importance in the very fragile and often little-explored natural environment of the many developing countries. Experience in the industrialised countries has shown that the added costs are more than offset in the long run, as accumulation of pollution problems and the high cost of repairing the damage are avoided or minimised.

4.20 - Conscious of the theme of the Study Week, we cannot close the list of Recommendations without the most profoundly felt appeal to all countries to do everything in their power to ensure better life conditions to those most in need. While considerations of cost, technology and political feasibility are very important, even more important is the constant reminder that we are "our brothers' keepers" and that we can best unite mankind by persuading men to build together. Thus we urge all we are able to reach with this message to keep ever present the development of the less developed countries. Energy plays a primary role in this, and our work in this Study Week has shown it also to be a problem with a major spiritual dimension.