Paths of Discovery
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TODAY THE WORLD OF TOMORROW – THE ENERGY CHALLENGE

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First of all let me say that this is the last presentation and it is therefore slightly different from the previous one. I did not feel like coming down and telling you about my own path of discovery, maybe it is a form of modesty or whatever, however, it is certainly true that this Council has been devoted to such a topic. Now, there is no doubt that new knowledge is driven by the discovery action. The many presentations we have heard over the last few days have well illustrated the different ways in which scientific progress may manifest itself, either through individual researchers or, as it is done more often today, through research programmes involving many researchers often from very different disciplines. Indeed, discovery has progressively transformed itself from a separate action of a single individual to a collective result of a wider community.

In the most advanced part of mankind, research initially from the isolated endeavour of a few scholars, has now become the main engine of social and economic progress of the society as a whole. We are witnessing the progressive transformation towards what is called a knowledge-driven economy with the discovery process being the main engine of progress.

The social consequences of such a deep evolution should not be underestimated. However, not everybody will profit from this immense gift to mankind represented by the scientific and technological progress. What I could call the scientific and technological illiteracy is becoming a persistent problem for a vast component of the world population. It is one of the main responsibilities of the more advanced societies, the one of providing free access of such a knowledge-driven progress to the most needy ones, today so essential in order to heal most of the crucial problems of the poor, like illnesses, poverty, lack of food, lack of water and so on. Contributing to the solution of these injustices is today configured as one of the most important missions to which the scientific community must actively contribute. In addition to these traditional problems a new situation is progressively emerging, initially due to the rapidly expanding number of individuals on earth which are now 6 billion people and presumably twice as many in not too distant a future, namely a rapid growth of extremely serious climatic changes as described last Saturday by Professor Crutzen. Such a presumable change in earth climate ahead of us, of which we detect only the first signs without the most serious consequences for the poorest part of the planet, since they are the least prepared to cope with such major changes which are forecast ahead of us. And indeed we should realise that 95% of such climatic changes are due to energy production. Energy supply has been a major element in our civilisation. Historically, energy for food gathering has been supplemented by energy for household use, initially heating, to organise our culture, industry and transportation. The total energy consumption of the most advanced part of mankind has grown about 100-fold from the beginning of history, reaching today the level of about 0.9 gigajoules per day per person, about one gigajoule to each one of us every day. This corresponds to the equivalent of burning 32 kg of coal per day per person or a continuous average supply of 10 kilowatts of power per person. Hence, the basic food supply represents today, for most of us, only a mere 1% of the total energy needed by us.

A most remarkable feature of the pro-capite energy consumption is the disparity determined by the differences in social progress. The present enormous disparity in electric energy consumption – Sweden 15,000 kWh of electricity per person per year, Tanzania 100 kWh per person per year – demonstrates a huge correlation between energy and poverty. But there is no doubt that the world's energy will continue to grow in the future since the population is steadily increasing and billions of people in the developing countries are striving for a better life. Hopefully the disparity in energy consumption may tend to converge. According to IEA World Energy Outlook, about 1.6 billion people, a quarter of the current world's population, are without electricity, which precludes the great majority of industrial activities and the related job creation. The majority (4/5) of these populations live in rural areas in the developing countries, mainly in Asia and Africa. About 2.4 billion people rely almost exclusively on traditional biomass as their principal energy source. Incidentally, in many of those countries the level of solar flux is such that it could potentially become a new primary energy source provided it is harnessed with simple and cost-effective technology.

It is well-known every bit of this energy, if produced by burning fossils, is multiplied by the sun as much as over a hundred times because of the increased CO_2 radiative forcing caused by the persistent trapping of the sun's radiation by the burnt fossils in the earth's atmosphere. In other words, the energetic toll to the planet is about a magnitude greater than the initial heat generated by man. So we have 1 but we produce 100. In the past, before the beginning of the seventies, in a first approximation the carbon cycle was closed in an equilibrium situation until human activities started to tilt the balance. Presently, CO_2 emissions are about 6 gigaton of carbon equivalent, namely 22 gigaton of CO_2, growing at about 2% per year. During the last 10 years emissions were 63 gigaton carbon, corresponding to 32 accumulated in the atmospheres and the remaining 30.4 absorbed by the ocean and by vegetation.

In comparison, the simple breathing of 6 billion people alone produces already about 1 gigaton of CO_2 yearly. We can predict with confidence that in the next centuries the continuative use of fossils without restriction will dramatically modify the earth's climate in ways which will impact in practice every living organism. Technological improvement will no doubt introduce other, more acceptable, forms of energy but the planet is notwithstanding continuing to burn a significant fraction of fossils for a long time to come, especially in those parts of the planet where technological change is slowest. The estimated reserve of fossils are about 500 gigaton carbon for oil and 5,000 gigaton carbon for coal. Coal reserves could be larger by a factor of 2 or 3 if also less noble forms of energy would be burned. Likewise recovery and new discoveries may contribute with substantial increases in oil and natural gas. The fact of the cumulative emission of as many as 5,000 gigaton of carbon of natural coal, progressively burned by people, will depend on which rate it is burned with a maximum CO_2 concentration which will be about 4 times the present level, presumably reached somewhere between 400 and 800 years from today. Since the recovery time is very long and what matters is only accumulated concentration, the result is only slightly dependent on the actual distribution of emission. Let us assume for instance that the fossil consumption of as much as 5,000 gigaton carbon, although being concentrated in only some parts of the world, continues for something of the order of 800 to 1,000 years to come, as it takes to use all the available carbon. Two thousand years from today the CO_2 concentration is still likely to be twice the present level. I must say that half of the coal flames produced by the burning of Caligula's Rome fire are still present in the atmosphere and are still taking away from us CO_2.

At the present consumption level, known reserves for coal, oil, gas and nuclear correspond to a duration of the order of 230, 45, 63 and 54 years. This effect will be affected positively by discovering new reserves, negatively by increased consumption. Even if these factors are hard to assess, taking into account the long lead time for the development of new energy sources, the end of the fossil era is at sight. And what after that? It may be worth mentioning that only 2 natural resources have the capability of a long-run energetic survival of mankind, beyond fossils, which incidentally as mentioned may be prematurely curbed by intolerable climatic changes. They are 1) solar energy and 2) an innovative, different nuclear energy.

The present world's energy consumption is about 1/10,000 of the solar energy available on earth's surface. On 1 m^2 in a good location (sun belt), it 'rains' yearly the equivalent of = 25 cm of oil. Several forms of renewable energy may bring major progress, provided an adequate level of research and development is becoming available in the near future: biomass, wind energy and especially a highly innovative technology based on high-temperature solar heat which appears capable of a major breakthrough in the field of energy production. This technology, based on the use of a simple concentrated mirror, following an ancient method of Archimedes of Syracuse, may produce vast amounts of both electricity and synthetic hydrogen from water splitting with high efficiency. For instance, the surface theoretically required to generate the full planetary electricity demand in 2050 represents the solar energy extracted from an area of 200 times 200 km square, somewhere in the vast equatorial sunbelt region. In comparison, the area today dedicated to agriculture is two orders of a magnitude larger, namely ten to the seven km square. A second alternative is a new form of nuclear energy from natural uranium, thorium or lithium or some other light element which is called fusion. If burned, it may be adequate for many thousands of years of several times the present energy consumption. It is still a very long range of development, it is unlikely that the practical industrialisation of such a very sophisticated technology may occur within the time-span of even the youngest amongst the presently active individuals. However, the necessity for the future generation of a clean and inexhaustible source of energy justifies why so many people are spending so much effort towards such a goal. One should primarily target new alternative methods free from the present fundamental drawbacks like radioactivity in the fuel, radioactive waste and, most important, proliferation potentials which are the main environmental, political and social problems facing today's nuclear power, in this way clearing the way for the widespread nuclear plants especially in the developing world.

To conclude, a coherent energy policy and strategic choices have to be made on nuclear power relying primarily on innovative scientific and technological discoveries in order to reconcile sustainable development and economic growth with a threat of environmental decay. Energy supply has been a major element in our civilisation. No doubt, the long-range future of mankind would be impossible without a continued supply of plenty of energy. The problem of energy focuses today the interests of politicians, businessmen, technologists and people at large. Everybody will agree on the fact that energy is an absolute necessity for the future of mankind, but the consequences of an ever-expanding energy demand should not be underestimated since they represent a growing concern for the long-term future of mankind, both in terms of environmental problems and of the availability of supply. Our society will depend crucially on an uninterrupted and differential supply of plenty of energy, therefore major steps have to be taken in order to avoid potential geopolitical and price vulnerability conflicts.

The inevitable growth of energy consumption under the sheer momentum of society and the very human expectations of the poor may indeed add enough yeast to make this aspect leaven beyond control. I believe however that like in the case of famine, illness, etc., also here science and technology should be trusted. Indeed, there are reasonable expectations that combined they will have the possibility of solving also this problem in full accord with economic, dynamic and technical constraints that the working system has to comply with.