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Nuclear Energy and Climate Change*

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Thank you for the opportunity to talk to you this afternoon. As you see, I am going to talk about climate change. If you remember Professor Rubbia's talk, he actually covered that in one paragraph in one of his slides so I could consider that we have already covered this topic and could go on right to the coffee break, but I am going to be very bold and talk to you anyhow and I am going to try to give you some complementary thoughts, but, as you see, we are very much in agreement on a number of topics.

I thought it might be worthwhile to spend a few minutes – I know all of you know what climate change is all about – but I want to emphasize the point, why is it that just in the last couple of years it has acquired so much visibility? We have known the basic science of climate change – I mean, it was really discovered in the 19th century – if you recall, what happens is the thermal balance of the planet is sort of delicate and the atmosphere plays a very important role and, of course, the planet is in a steady state, we could say, of thermal equilibrium, we receive energy from the sun and the planet loses the same amount of energy, on average, but in the form of infrared energy so the atmosphere functions like a blanket and it warms up the surface of the planet. On average it is from -15 to about +15°C. This 30°C change is what we call "the greenhouse effect"; better speaking, the "natural" greenhouse effect. Part of the complication in explaining this to the public is that human activities are changing that balance only slightly, and yet the consequences are indeed very important. So how are human activities changing that? Well, you know what we are doing, basically we are changing

* Slides are unavailable.

the composition of the atmosphere and it is very well-established and very clear that this change is a consequence of human activities. So what I am going to do is show you two or three pictures that come from the Intergovernmental Panel on Climate Change, the one that shared the Nobel Peace Prize with Al Gore in 2007, I believe. This Panel makes a report every four or five years, and in the last one the scientific part came out in early 2007, so these are pictures taken from there and you can see, on a geological timescale, the sudden change in composition in these gases that absorb infrared energy, the most important one being carbon dioxide that has gone up almost 30% now but there are others, methane, nitrous oxide and so on. So I should already point out here that carbon dioxide is a little bit over half the problem. There are these other gases and also black carbon or soot that I was not planning to talk about but they are also very important and, if we have time, I could make a few comments on them as well. Anyhow, this is the change in composition and this is the change in temperature. It is the average temperature of the surface, which was not particularly easy to measure until recently, when you have thermometers all over the place, but if you go back 1,000 years you have to do it indirectly, and that is why there are different interpretations. What I just showed you are just measurements. The conclusion of this IPCC Panel is that these two observations are indeed connected, and that this temperature change is indeed a consequence of the change in chemical composition. However, the climate system is rather complicated so we are not really sure. What I am saying is that we are not absolutely sure, so what IPCC did was to talk about probability, something that I am proud about because, already in the previous IPCC report, together with a couple of colleagues we were pushing to incorporate the statistical view of things. So the conclusion is that there is a mere 95% probability, sort of, that this is a consequence of human activities, where for all practical purposes that is certainly more than enough for society to act on it if we worry about it. We do not need 100% and yet, this is one of the misconceptions with the public at large, they expect science to be perfect, and that certainly is not the case, climate is indeed complicated.

You know all about the IPCC Panel. I belong to that Panel, by the way, we do not do research, we just summarise whatever is in the literature and we are actually rather conservative so what I am going to show you a little later is some of the more recent findings that have come after this 2007 Report.

What is the evidence then? Well, there are lots of observations, it is not just based on models, this 95% that I am talking about is not based exclusively on these very complex models of the climate of the world but it is based, to a large extent, on observations. We know glaciers are melting, not all of them but many of them. But the most worrisome component of climate change, which is relatively small, after all – I should have pointed out that temperature changes less than 1°C, 0.6°C-0.8°C – is extreme weather events. So floods have increased in all continents in recent years. We have examples, of course, in the US and Mexico we have had lots of flooding recently and also wildfires, forest fires and so on, but the other extreme event that is very worrisome are droughts. So the amount of rain falling on the planet has not really changed that much, it just has changed the way it comes down. Droughts are particularly worrisome for agriculture, for food production, and we can also see how that recently has really increased, has doubled in the last 30-40 years the amount of what is considered very dry land.

So the impact, which I will not go into detail, has to do with this temperature increase, the way the hydrological cycle is affected and, of course, sea level rise, because one worries, as you get melting, not only of glaciers but in the North and South Pole, Arctic and Antarctic, and also thermal expansion of the oceans is what dominates so far, you get sea level rise that threatens all sorts of coastal areas, including small island states that have a tendency to disappear, as you know.

What I am going to do is instead summarise the impacts in this way, which I took from my colleague, Sir Nicholas Stern. He just summarised the same effects that we had in the IPCC as a function of temperature change and you can see a variety of effects: food production, water, ecosystems and so on. I want to point out the second arrow, it is often a criticism to the IPCC, there are certain beneficial effects of climate change, like larger seasons for food production in northern countries but overwhelmingly the effects are really negative because these extreme weather events essentially cause a lot of damage. I also want to call your attention to the last arrow, so if I have time I will talk a little bit more about that towards the end, which is what we call "abrupt climate change", which is very hard to predict or estimate, but the probability of those events increases quite rapidly as the temperature change goes up. Now, because of this sort of analysis the consensus – not just among climate experts, you now talk about economists and people in governments – there has been a general consensus that it would be wise not to let the surface temperature of the planet rise above 2°C, that is going back to the UNFCCC principles that you want to avoid dangerous interference of human activities with a climate system. So, above two degrees is what is, by consensus, considered to be dangerous. So that is the goal, how do we go about it? The bad news is that we are not on that path, we are just looking at CO_2 here, there are ways of looking at CO_2 equivalents where you incorporate the other gases that I have mentioned. But CO_2 is the main greenhouse gas, the one associated with the production of energy, which comes from the combustion of fossil fuels that have been so important for the growth of the economies, particularly in the developed countries. So we are now on the red line and if we look way ahead in time, several centuries ahead, if we want the temperature not to go above 2°C we have to change from the red to the yellow line, so it is really a challenge to change to the blue and so on, but we can no longer delay starting this change because it is going to be very much harder to do if we wait another decade, because, particularly CO_2, accumulates in the atmosphere. To begin with, about half of it remains in the atmosphere on a slightly longer term, about one third, 30% remains in the atmosphere, but it remains there for about a millennium, so we are really committing many future generations, not just our children and grandchildren with CO_2. So that is the challenge. Here is the good news. I am taking this more or less historical graph now from my colleagues S. Pacala and R. Socolow from Princeton because they were the first ones that pointed this out very clearly. Here I have again these emission curves: you can see the growth of the emissions, the number of tons per year as a function of time, but now the timescale is much shorter, basically just the first half of this century, but we have to change, to remove essentially the green area above if we want, in this case it is even less stringent, not 2°C but 450ppm which actually means more than 2°C. But the answer is the following: if you look in detail, there is no silver bullet. We are talking about nuclear energy: nuclear energy will not work to do that change. Even solar energy, I think that it is exceedingly important, I essentially agree with Professor Rubbia's conclusions, but solar energy alone will not do it, so we need to consider all these so-called wedges, and we have to act on all of them simultaneously, knowing ahead of time that maybe not all of them will work but it is just a gamble we should not take.

And now, interestingly, the first few wedges are all improvements in energy efficiency, we just heard about it from Professor Rubbia, so that has an enormous potential and we are nowhere there yet, but we know, technically, technologically, it is quite possible. We can improve the energy efficiency in buildings, in transportation, by something like 30% without technological problems. So that can be done, why has that not happened? Well, that is because fossil fuels are very cheap, they are so easy to exploit, and so on. Of course even that is changing, because they are beginning to be harder to exploit, but much of what has happened so far is a consequence of the availability of fossil fuels and so there has not really been a big concern about prices in that context. But then let us look very briefly about others. You see how my talk nicely complements Professor Rubbia's. I will not discuss the details, wind energy, solar energy, Professor Rubbia covered that in an excellent way, and again, in summarising, I certainly agree with him. Solar energy has been very much underutilised, for example in Mexico we have a huge potential we have not even started, but that has to do with this question I stated, this perception of the importance of climate change is really relatively new, it is just in the last couple of years. There is another reason I will get back to that in a moment. First of all, just a brief comment on biofuels: there was a misconception initially that again was considered to be, that is going to help a lot, solve the problems, but we have to look at that carefully because it can compete with food production and, at some point, because of the European demand for biodiesel some forests in Asia were being torn down. That is, of course, unacceptable from an environmental point of view. So that type of biofuel does not have environmental advantages, so you have to look at it much more carefully. I will just point out that another potentially important activity is carbon capture and storage, why is that? The point is, fossil fuel is limited. We still have enough to cause a lot of damage but, the point is, we are probably going to run out of fossil fuel in a few decades, particularly if we continue using it at the same rate, but we are not running out of coal in the planet, the United States and China have a lot of coal, certainly enough to make a mess of the climate. So the only way that you can use coal and protect the climate by decreasing emissions of CO_2 is by capturing it and storing it and this concept in principle works but it has not been tested on a large scale, so it is something that remains to be done and of course that increases the price of the use of fossil fuels.

Let me just move on. Since we are talking about nuclear, we have already covered these areas but I will just very briefly repeat that. Of course, nuclear power already provides a certain fraction of the world's electricity, 20% in the US and so on, in France, as you know, more than 3/4 but these advantages, again we have covered all that so I will not discuss that any more, radioactive waste, accidents and so on, but what one could argue is that radioactive waste is actually something that is technically manageable. The amount of waste is relatively small if you compare it to the amount of CO_2 that is produced but it is something that, in principle, society should be able to cope with. Of course, you have the long timescales and so on, and uranium being scarce, so we covered all that. Furthermore, something perhaps that we did not point out is that the timescale to build a nuclear power plant at the moment is very long, particularly in places like the United States, and it is not particularly cheap, although that depends on how you look at it, because you have a fairly large investment and on the other hand, once you invest in it, you can have it for many decades, fifty years or so.

But the main worry, I think the main worry remains the potential for nuclear proliferation which is, in some sense, what we are talking about here. We might come back to that but that has been discussed here quite extensively. It is still a very big worry and, if I can summarise what the situation is, as I see it, we do not have yet the technology to produce, to generate electric power with nuclear fission without the threat of generating also weapons material. Perhaps these thorium-based plants, or so, but that is a high priority activity for society at large, if you want, to retain this option, to go along with this idea that we should have at least all the options that these wedges point out, not necessarily to point out that that will be the solution or even the most important one, it is just an insurance. Society should have that option just as one more option to solve the problem but we should really worry about nuclear proliferation. Some sceptics point out that, look, the problem is already there, there is already enough material out there to produce bombs, so why worry about making more? But if you really do that on a large scale in developing countries, well, again, we have covered that.

So let me go back now to this probabilistic view. I am summarising here the results from my colleagues at MIT. As you know, I spent many years at MIT so I worked together with this group on the Joint Programme for Climate Change with Ron Prinn and Henry Jacoby, they have a very large model of the economy coupled with a model of the climate and the way Ron puts that, normally, when you want to talk to decision-makers in governments, we are playing a game of roulette, that is one way to look at it, and right now we are on the roulette of the left, and there is some significant reason that the temperature will change more than, say, 4°C and that is really unacceptable because the consequences of such a large change could be very damaging, particularly for large portions of the population. If we wanted not to go above 2°C, well, it can happen but it is a gamble. But if we change roulette, we have much better chances, we cannot ensure that, but the point here is the economic story. Again, the point of presenting this as a game of roulette is, let us say we are betting $100,000, how much would you pay me to change the roulette, if the gamble is for the temperature not to go above 2°C? And any gambler will say, well, it is a much better roulette, I am willing to give you $20-30,000 of my $100,000 if I can play the new roulette. But the interesting thing, as you probably know already, is that the economic stories show that this change costs only about $1,000 so we are talking about 1 or 2% of global GDP to implement the wedges we talked about. So that is quite feasible, the problem is who does that and what you have to do, developers and developing countries. Here comes the bad news. That was as you saw in 2003, just before the first Report of the IPCC but the new signs, this is looking at more detailed observations, the role of particles that have partly masked the effects of climate change from greenhouse gases and so on, so this looks a lot worse. That means if we do not change, we now have maybe a 25-30% probability of real catastrophes, namely these red portions, if the temperature goes above 5°C you are really in trouble, at least statistically. Not that it is a most likely event but we can have very important effects. Again, I will try to get there.

But the point is that this 1 or 2% cost has been analysed in quite some detail, maybe it is an underestimate, but the point is that there are a number activities here from these McKinsey Cost Curves relates to energy efficiency that do not cost. And eventually, if you want to do things like carbon storage, then you are talking about maybe $20-30-40 per ton of carbon dioxide emitted. So these are important analyses but they have actually been carried out with existing technologies, betting on the development of some new ones.

So let me summarise then, what needs to be done to address climate change? We talked about that in the previous session already. It is very important to have some sort of international agreement that puts a price on carbon emissions. To incorporate this into the economy, maybe not explicitly each esternality, but that is the deal that is trying to be worked out, for example in Kyoto, in Copenhagen and so on and it does not have to be very dramatic. Again, it can be done at a very reasonable cost for society but we also talked about underinvestment in energy technology, I will not repeat that any more, but international cooperation is also extremely important. Much of the problems, the emissions for the next decades, not right now, now China and the United States are emitting just about the same amount, but in the future it is going to be the developing world so it is crucial for there to be international cooperation for the development of these new technologies. If that is done in cooperation, you could even conceive of nuclear energy. If it were done not country by country but in some sort of open international way chances would be much better for it to be feasible. Win-win measures, that is what I am talking about. Energy efficiency. I think my time is almost over but I will just mention that we call these irreversible problems that we are worried about *tipping points*, and tipping points just mean that we can change the state of the system, and this is just the analogies here with the position of this little ball, if we move the position from the front to the back, which is what we are doing now, with a relatively little push we might be moving the climate system a long way. Here are just some predictions, what sort of things might happen. Arctic sea ice is already melting, but we could have drastic change in weather in the Amazon, so disappearance of the monsoon in Asia, these are things that we would be committed too. Once it is triggered it is largely irreversible. Well, that is an exaggeration, it would be reversible but on a timescale of many millennia, so for practical purposes we really do not have a choice.

Let me just finish with one or two graphs. What is the planet doing? We just had this meeting in Copenhagen to follow the first meeting in Kyoto. As you know, the Kyoto Protocol was not ratified by the United States and by Australia. Australia has already ratified it, so the dilemma is, for equity reasons, since the developed nations are the ones that have emitted most of the greenhouse gases it is only fair that they should help the developing nations to grow their economies with a transfer of funds. It is not a huge transfer but there is a big fight as to exactly how to do that. But if everybody collaborates, that certainly can be done.

Just to finish, let me go back to the question I raised at the beginning. Why is it that this problem has acquired so much importance recently? I mentioned the science but the second point which I think is not trivial is, it has made it to the attention of the Heads of State, there were over 120 Heads of State in Copenhagen and essentially all of them agreed that we should go for this no more than 2°C change in the temperature. There was no objection to that. All the objections were, how do we do it, how much do we have to pay, do we get a binding agreement, it is enough for one nation to say no, and you know the United Nations has again this system that we discussed, that just does not work, so we have high hopes that, given all this impetus that we have now, in Mexico, with the next conference of the parties in November, we will be able to do a lot better but we certainly have a huge need to act, that is again the bottom line of why we say this is an urgent problem and we can have really global disasters if we do not act on it soon enough. Thank you for your attention.