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Our session is called energy and climate change and I want to remind everyone that while these two issues are closely related, climate change is due to more than energy. In particular, roughly speaking, one-quarter of greenhouse gases come from agriculture and changes in land use. When we think about climate change, we have to think about not only energy. We have to think about other sources of greenhouse gas emissions as well.

We all heard Laurent Fabius talk to us last night about the urgency of dealing with climate change. He has been involved in an intimate way now for at least 10 years. He reported on the latest IPCC report, which I have not read. I only learned about it from a few newspaper articles and what he said last night. However, two things surprised me about what I have heard.

One is its specificity. I have followed the science of climate change for at least two decades, as an interested observer, not as a scientist. There are still huge uncertainties, including the sensitivities of the climate itself to greenhouse gas concentrations in the atmosphere. They have not changed in 25 years. 1.5 degrees Centigrade to 4.5 degrees Centigrade for a doubling of CO2 from roughly 1800. We have invested tens of billions of dollars in research on climate change. We know much more than we did 20 years ago, and one of the things we know is how complicated the earth's atmosphere and oceans are. We are much better informed on individual pieces. In spite of this, we still do not have an accurate overview of climate change and its relation to greenhouse gas emissions.

Given that background, I was surprised at the specificity that was reported. Again, I have not read the report, but it was reported in the newspapers and in Fabius's speech last night. In order to get that specificity, they had to make a lot of assumptions about things that we do not actually know. They may be completely right in those assumptions. I do not have a judgment on it, but they may also be badly wrong. We should not take that as firm knowledge about the climate, even from accomplished scientists.

There is another thing that surprised me. Again, this is from newspaper articles and Fabius's speech. It is the degree of urgency which was conveyed apparently to the readers of the report and maybe by the report itself. There were statements about 2030. I would just say flatly, as a practising economist for a half a century, that we cannot achieve a permanent 1.5 degrees Centigrade by 2030. We should get it out of our heads. We are not going to turn society over around the world over the issue of climate change. It is just not going to happen.

What might happen is that we overshoot, and then technological improvements permit us to go back down to 1.5. I do not rule that out, but the notion of stabilising the average temperature increase at 1.5 degrees Centigrade by 2030 is out of the question in my view. We need to think about this much more actively. If the scientists are right in what they say, we must think more actively about adaptation along many different fronts, not just building sea walls, but with biodiversity and so forth.

Human agency can adapt. Of all of the species, the most adaptable are human beings, along with probably some ants and some bacteria. Human beings have an enormous capacity for adaptation to change, particularly if there is notice about when the change is coming, as we increasingly have. It is bad politics to urge strongly that we do something that is going to be impossible. That sounds like Mr Trump. He wants some things which are impossible.

I know that a number of environmentalists, at least in the United States, and I gather in Europe also, deeply regret the shale gas revolution. This is on the grounds that it is another fossil fuel and it generates greenhouse gases. They are correct in their factual statement, but per unit of useful energy, in producing electricity, natural gas produces about half the greenhouse gases that coal does.

My trajectory is not for the next decade, because I think it is impossible, but for the next three decades. Natural gas is the bridging incremental fuel and solar is the ultimate source of energy, supplemented by wind and other things like geothermal. However, the ultimate main source will be solar, and as we have heard in the previous presentations, the cost of solar energy has come down dramatically within the last decade.

In the short run, the thing we need to do above all is prevent the building of new coal-fired power plants, which contribute greatly to climate change and are heavily polluting. Then there is the question of what we do with existing power plants, those that still have economic value. That is an issue, certainly for private firms, as in the United States and some other countries, but even for state ownership of coal-fired power plants. That is an important financial decision.

There are coal-fired power plants, which have very low operating costs once the capital costs have been incurred and which last for 40-50 years. Are they going to be taken out of production? Can we have an international agreement on that? Probably not. Can we have an international understanding that it would be desirable? That is probably feasible, leaving aside Mr. Trump for the moment.

Then it would be up to individual countries the extent to which they accelerate the shutting down of existing coal-fired power plants, but above all, we have to stop building new ones. Coal is still very important in the United States, but we have not built any new plants for the last 35 years. All the incremental power has been achieved by natural gas, which has higher operating costs but much lower capital costs to build. We have expanded some existing coal-fired plants, but we have built no new ones.

Then, if there is a bridging period from natural gas to solar, the issue of electricity storage comes up, which has been emphasised by our previous speaker. I am glad she did not use the word batteries, because batteries are one form of electricity storage, chemical storage, but there are other forms of electric storage. What we could call batteries in general are perhaps necessary for electric vehicles which move around, but they are not necessary for stationary sources of power.

There are the traditional ways of storing electricity. We are pumping water, when the wind is not blowing and the sun is not shining. That only works if you have a lot of water which you can pump. You have flywheels. Flywheels have been understood for many years. They are relatively cheap to build. To build a first-class one requires special materials, but ordinary ones are cheap to build. You can imagine flywheels under any collection of wind turbines, flywheels which store the electricity and which can be drawn on when the wind is not blowing. For mobile things like cars, trucks, and aeroplanes, chemical batteries are much more important unless we go to hydrogen as a fuel.

Under the heading of climate change, I have long favoured nuclear power, so I am not a conventional environmentalist in that sense. However, as we have seen today, nuclear power is now outclassed in terms of cost, unless we get new, smaller, modular nuclear power plants. These have been designed at MIT and in other places, but we have not seen them yet in commercial use. They remain to be tested.

I saw a press report recently on fusion, saying that practical fusion, commercial fusion, was five years away. I am old enough to know that it has been said that fusion was just within two decades since the mid-1950s. I simply do not believe it, and I am not willing to put more money into it as a taxpayer. Some people are apparently, so we are still working on fusion, but I do not see fusion as a practical source of energy.

In talking about timing, I am persuaded of the tremendous inertia in human affairs, even in such rapidly growing economies as China and India. It is higher in more slowly-growing Europe and the United States. We have a large legacy capital stock in the United States and Europe. We heard in an interview from Carlos Ghosn today that there are now 9 million cars in the world.

In the United States, the average car lasts eight years. That is the average. I drove a car once for 14 years, from the time it was made until the time I sold it. Actually, I did not junk it, but I sold it to another user. Think about converting those 9 million cars, all internal combustion engines, into climate-change friendly vehicles. If we were to stop producing internal combustion engine cars this year, and from January on, produced only electric cars, it would take nearly two decades to replace the outstanding stock of cars. There are also trucks and other vehicles. And I want to remind everyone

that we cannot just look at the vehicles that are electric. You have to look behind it to how the electricity was generated. We still generate most of our electricity with fossil fuels, so you have to look at the entire cycle and not just the fact that the car is electric.

Let me say a word about Mr Trump and his withdrawal from the Paris Agreement. He announced his intention to withdraw in June of 2017 and as you probably know, it takes three years to formally withdraw. He announced his intention to withdraw. By coincidence, two weeks later, we had an annual conference of mayors. It represented 1,400 cities, all of the largest cities in the United States. The conference of mayors, Republicans and Democrats, voted overwhelmingly that they were not giving up on addressing climate change.

It has to be said that not many cities have a climate change policy, but surprisingly perhaps, many US cities, including mine, Cambridge, Massachusetts, do have a climate policy. The conference of mayors, in direct reaction to Trump's announcement, announced that they were going to carry on. We know some states, with California upfront, but it includes Massachusetts and other US states are going to carry on with climate change policies.

The time dimension of these policies to address challenges is such that Trump will come and go before it has been solved seriously. Trump can do a lot of damage as president, but it is not mainly in this area. Things are going to carry on. They are going to be driven mainly by market phenomena. We have talked about the changing cost structure for solar, wind, nuclear, and coal. Climate change is not high on my list of the damage that Trump can do. I could say lots more, but it is probably time to stop.

Nobuo TANAKA

As you say, this IPCC special report mentioning 1.5 degree was just released. They are very ambitious, surprisingly tough, and very specific. Making net zero emissions by 2050 is necessary. Compared to that two degrees Celsius scenario, we need three times or four times more investment. As you say, if overshooting happens, the carbon capture and storage or usage will definitely be the key technology for achieving net-zero emissions by that time. The technology is there for carbon storage and capture, but without the carbon price or carbon tax or some kind of penalty on carbon, this is very difficult.

Some companies in the United States have carbon pricing and are reducing the carbon contents. However, this carbon capture technology is only possible in Saudi Arabia or these oil-producing countries, as they enhance their recovery. However, burning coal, taking out carbon dioxide and putting it underground is probably almost impossible. The other technology, direct capture from the air, is also discussed, but this is another very high cost.

Other things include the battery of electric vehicles as a system. If there are millions of electric vehicles on the market or on the street, they could be connected, and they can provide the gigawatts of storage as a system. That is one of the Chinese strategies that some of the EV companies are thinking about. Digitalisation and connectivity are part of this storage programme. Fusion is interesting. I have learned that some of the fusion companies in the United States are really ambitious, and with some of the money venture capitalists have put in, I hope one of them may work. However, we will see.