BP
Future Perspectives
Solving the Carbon Problem

Carbon Mitigation Initiative
Princeton University

Music

Commentary: **The operation of the Earth's biosphere is extremely complex, and understanding that complexity is a major scientific challenge. It is, however, a challenge that must be faced if we are to solve the carbon problem – the increasing amount of carbon dioxide in the atmosphere due to the burning of fossil fuels, and the changes in the climate that appear to be linked to it.**

Even with current temperature levels, the world is beginning to experience sea level rise and an increase in extreme weather conditions. We need to reduce the rate of C02 emissions, but without causing severe disruption to the way we live.

Title: Future Perspectives – Solving the Carbon Problem

Princeton University is the home of the Carbon Mitigation Initiative. Established in 2000 by BP, with additional support from the Ford Motor Company, the CMI is developing radical new approaches to carbon management...

Bernie Bulkin: I think it's clear that global climate change is the biggest issue facing everyone in the energy industry. And BP really has made a commitment that we need to be involved in this at the state of the art of the science and we in fact need to push the state of the art of the science.

The Princeton programme brings together people from a wide variety of disciplines, from geosciences, environmental sciences, chemistry, mechanical engineering, ecology. A whole range of people who in fact hardly spoke to each other before, to attack the carbon problem.

Prof. Robert Socolow: This is a unique programme in having the science and the technology and the policy all in one group, which is a closely knit group. We're about 50 people from the students through the faculty, working together.

Commentary: **If the carbon problem is to be solved, it can only happen on the broadest scale. The CMI operates across a number of areas: the development of new technologies for the capture and storage of C02…policies for choosing and implementing the different possible strategies for reduction…and a deep understanding of the planet's carbon cycle...**

Prof. Steve Pacala: Well, the first area is science. And it's basic scientific research about climate and climate change. So we actually build the giant computer models that integrate knowledge of how the atmosphere works and how greenhouse gases affect the atmosphere, how they trap heat next to the surface, how the oceans interact with the atmosphere, and there's models of the terrestrial biosphere.

These things are pretty highly advanced. You take these computer codes and you start with a world that doesn't look like the Earth at all, and the Earth will self-assemble. And then we add greenhouse gases and watch the climate change. We try to study why it does, and what of the myriad of effects that do occur, which ones occur and why they occur and where.

Ants Leetma: We work with the carbon mitigation initiative at Princeton University on two fronts. One is we model the natural carbon cycle. Currently half the carbon that goes into the atmosphere is taken up by the land and the ocean. And so one of the key questions is how will that change as the planet warms. And that will determine how much carbon we actually have to mitigate with technology.

The second aspect then is that once they propose some solutions which would reduce the emissions, we then want to see what that reduction actually means in terms of the planet.

Prof. Steve Pacala: We've made real progress in improving climate models over the last 18 months, really extraordinary progress by a lot of objective measures - how well the models predict current climate for instance. We've closed the gap between what the models predict and what the data says by more than half over the last 18 months. So we've really made progress there.

Commentary:

The capture of CO2 before its emission into the atmosphere is the second area of focus at Princeton. One way of doing this is by removing CO2 from the exhaust gases at a power station or industrial plant after the fuel is burnt…

But it can also be done before the fuel is burnt – through technologies that separate out CO2 and hydrogen from coal and gas and then burn the hydrogen as a clean fuel.

Part of the Princeton programme involves the study of the nature of hydrogen itself and how it can best be used as a fuel…

Prof. Ed Law:

Well, we're basically interested in the utilisation and combustion of hydrogen, which is a very good fuel as far as the emission of C02 is concerned because there's no C02 emission. We have found that when hydrogen burns, it burns in a very rapid mode of burning.

But in addition we have also found that when regular hydrocarbon fuels, for example propane, when it burns it burns very nicely. It doesn't have those wrinkles. So then we make the suggestion that maybe we can mix some hydrocarbon, not too much, with hydrogen so that the burning could be smoothed. And then in a sense you moderate the burning intensity of hydrogen.

Prof. Robert Socolow: On carbon capture, we have begun to understand pretty deeply how relatively inexpensive it is to capture carbon dioxide from a coal plant or a natural gas plant. It will not break the bank. It will make energy more expensive, but if we need to do it we know how to do it. It will not be more than 50% more expensive, probably a good deal less than that, to have electricity produced from coal, let's say, or natural gas, without the C02 going into the atmosphere. There'll be a price premium, no doubt, and we have to decide that we care about the problem enough to spend that money.

Commentary: **Having captured CO2, the next challenge is to do with its storage, otherwise known as sequestration. One way of doing this is to store it in geological formations such as old oil and gas reservoirs. Looking at the feasibility of carbon dioxide sequestration is the third area of the CMI's work...**

Prof. Steve Pacala: Oil and gas reservoirs that you would put carbon dioxide gas in typically contain old wells, wells that were drilled long ago and completed before the current high level of technology was available. And there's a concern that C02 in them could possibly corrode the completion seals and cause them to leak.

Andrew Duguid, PhD Student: My work is on well cements and how abandoned oil wells and abandoned gas wells may be used as

conduits from deep subsurface sequestration sites back to the atmosphere by carbon dioxide. So I'm looking at the interface between the cement and rock in the well. And then I'm also looking at how the well cement degrades when exposed to carbonic acid, which is a product of carbon sequestration.

Commentary:

As clever as the science and technology of carbon mitigation might turn out to be, the initiative recognises that it will not work without the right policy measures - involving anything from local carbon taxes to legislation on a global scale.

The Princeton team has defined the steps that can lead to stabilisation and looked at the variety of ways of achieving that. Out of this has grown the *Wedge Game* - which enables the team to look at the tough policy choices that need to be made.

Several teams explore different ways of reducing the rate of C02 emissions by constructing a wedge. This represents the 175 billion tonnes of carbon that will need to be kept out of the atmosphere over the next 50 years, if C02 is to be stabilised…

Prof. Robert Socolow: You ask individuals what's your favourite one, then their favourites will be different. Then you can visualise a political process which in some sense involves negotiating among people whose favourite solutions are not the same to arrive at something which gives something for everybody but not everything anybody wants.

Commentary: **As well as working out the policy options, the programme looks at the costs of implementation, including that of not acting now…**

Prof. Steve Pacala: We've been able to cost out for instance a policy of doing nothing, of waiting. We call it an economics of regrets. And the results are surprising. It gives one a very different take on the need to act now.

But the main contribution there has been to apply relatively standard economics to the portfolio of existing technologies, and discover of course that although costly this is not titanically costly. It's costly at the sort of 1% of GDP level.

Montage

Bernie Bulkin: Princeton is one of the great centres for carbon cycle science and for modelling of the whole carbon systems. And for understanding the carbon system and bringing that together with the sequestration idea and developing the ideas about how to do something of this scale - this is a huge

scale problem – to do something massive in order to have an impact.

Prof. Robert Socolow: Our goal is to build the world's courage that we can work on this problem together across nations, and over a couple of generations we will be able to bring the Earth into some greater balance than it would otherwise be. We don't have to load this problem onto the generation, two generations or three generations from now. We can do it in this half century instead of putting it off to the second half of this century.

Prof. Steve Pacala: The best possible outcome for me is a new alliance. A new alliance globally that leads to a solution to this problem in our lifetimes. It won't be a completed solution. What it will be is a path, we'll be on a path so that if we just stay the course this problem will be solved. We won't leave it to our children and grandchildren and we'll do the responsible thing for the planet.

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