Introduction to CMI (Steve Pacala and Rob Socolow)

The Carbon Mitigation Initiative (CMI) has been extended to 2020. CMI started in 2000. During that time, while the low-carbon technology emerged, its application was uneven. At the same time, scientific advancement in climate science was enabling better prediction of future climate change. BP was thus motivated to explore some key questions raised in this general context of technological and scientific advancement related to energy and climate. And the sense was that CMI could sharpen BP’s corporate perspective on climate change and could present the policy-related issues that spring from CMI discussions. For this year’s CMI annual meeting, the impact and implications of some of the new changes and information will be discussed including the emergence of shale gas and the IPCC fifth assessment report.

Steve Pacala, “The Land Sink, Extreme Events”

The land plays a crucial role as a global carbon sink. Model simulations and field experiments have been performed to analyze the impact of doubling the concentration of CO₂ on the terrestrial carbon sink. Studies show that the plants can overcome the nitrogen-limited situation under the condition of high CO₂, which suggests that the land carbon sink is relatively robust. Nevertheless, other studies show that the occurrence of extreme climate events such as heat waves has become more frequent. It is still uncertain how the extreme climate events will modify the land carbon sink.

Discussion:

Regarding CO₂ fertilization, the Duke free air carbon dioxide enrichment (FACE) study showed unexpected robustness of the land carbon sink. Is that experiment too controlled i.e., is only doubling the CO₂ in the air but leaving the rest of the environment unchanged enough to make predictions about the land sink?

• We may be only now understanding the interplay between CO₂, plant life and the land carbon sink.
  Please discuss the misrepresentations of photosynthesis temperature dependence.

• Paul Gauthier’s new study this year, which carefully decoupled respiration and photosynthesis, showed that temperature has a large effect on respiration, but a smaller effect on photosynthesis. Previously, respiration and photosynthesis were thought to have the same temperature dependence.
Given the new science of 2014, are the risks of climate change more or less scary?

- The resilience of the CO₂ land sink is a very good thing, and the risk of the land sink “failing” has been pushed to the end of the century. However, the risk of extreme weather is already here as evidenced by statistics over the last 5 years, and 5 years ago we likely thought we had more time.

**Jorge Sarmiento, “Southern Ocean”**

Understanding the Southern Ocean circulation is important to represent the role of oceans in global climate models, especially for the processes of heat and carbon exchange. Nevertheless, in the past, due to technical difficulties, few field measurements have been conducted in the Southern Ocean. Since September 2014, with the launch of Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM), Argo profiling floats are able to perform measurements at an unprecedented number of locations with rich physical and biogeochemical data transmitted wirelessly. This will improve our understanding of the Southern Ocean and eventually help improve the ocean models.

**Discussion:**

Can you make any comments about the preliminary SOCCOM data, especially the factors (temperature, pH, etc…) surrounding the “spring bloom”?

- The goal of SOCCOM, and particularly Princeton’s involvement in SOCCOM is to take the experimental data and feed it back into the models to make stronger predictions about this vital but under-researched part of the oceans. There are not yet any comments surrounding the “spring bloom”.

Can you summarize how SOCCOM will reduce the uncertainty of climate change?”

- Circulation of the oceans is key to the oceanic carbon sink. Thus SOCCOM is the first high fidelity way to observe this circulation over a number of variables (temperature, pH, Nitrogen content, etc…). Its results will be used to make global climate and carbon models far more accurate and predictive.

Does the fact that Pacific water takes 1000 years to mix with the deep Southern Ocean imply that man-made climate change will change the oceans only very slowly?

- Yes, the deep oceans especially can only change on a slow time scale. We do not know enough about all the implications of increasing the atmospheric carbon on the oceans, but to our knowledge now the oceanic carbon sink is stable for the foreseeable future.

Can you give any quick take-aways from the talk?

- The ocean is our greatest carbon sink and we need to study it carefully.
- Understanding the ocean is key to understanding climate change through effective climate modeling.
• The SOCCOM will provide us with new data on a critical part of the climate. We hold no predetermined bias when studying these data. That is why the key points, predictions, and findings of this study will take time to realize.

François Morel, “Ocean Acidification”
Though the chemical mechanisms of ocean acidification are well understood, the biological implications are complicated. How high latitude oceans respond to climate warming and CO₂ uptake can be studied via photosynthetic biomass production of flora in such environments. The findings will provide a basis for representing the biological processes in these high altitude oceans in the Earth System Models.

Discussion:
You mentioned that in the short term the mollusk growth rate has not been a problem. However, when should we expect “oyster shortages,” given the rise in atmospheric CO₂ affecting calcification?
• The larger threat to mollusks is not the carbonate but disease brought on by some indirect link to climate change. Additionally, oysters tend to be a very resilient organism, and some of the microorganism mollusks would provide the first signal of calcification leading to endangered populations of mollusks. Also, the question of “when” a population declines because of acidification may not be as useful as “where,” as the local environments will play a role in the demise of a creature before their global numbers dip.
Is there a depth dependence to the acidification and possible loss of marine life?
• Yes. The currents which circulate water into the deep oceans are very slow, and thus the shallow waters will see this acidification first.

Thomas Delworth, Research Scientist, GFDL; Lecturer, Princeton University, “A Link between the Hiatus in Global Warming and North American Drought”
The unusually strong easterly winds in the tropical Pacific are a major contributing factor to the hiatus. The initial surface temperature cooling due to the enhanced easterly winds is a transient feature, which will be replaced with warm temperature anomalies after a decade or two.

Discussion:
Do other models explain the hiatus? and how well?
• Some models for the hiatus cannot account for the total hiatus but can come close. This model however not only predicts the hiatus and the drought it accurately predicts observed seasonal variations.
How does this explanation fit with the “stepped” hiatuses mentioned by Steve Pacala and are all the previous hiatuses caused by the same mechanism? Are we any closer to being able to predict when a hiatus will start and stop?
• There is strong evidence that the mid-20th century hiatus was caused by the widespread use of aerosols. Thus, we do think each of the hiatuses observed since the industrial revolution is unique. Much more research needs to be done to achieve predictive power about when a hiatus will occur and for how long.


Two new schemes: committed emissions and carbon budgets have been introduced to estimate the future greenhouse gas emissions.

Discussion:
Increasing the use of renewables and economizing carbon are both simple and effective ways to mitigate atmospheric carbon and therefore climate change. However, we must be wary of oversimplification of the strengths and effects of these ideas. There is no one-size-fits-all solution. BP is interested in taking a dynamic approach to carbon mitigation rather than an “all-in” approach with a single seemingly simple idea.

Chris Smith, “Pathways to a Carbon Capture Sequestration Industry (The Government Role)”

Chris Smith, Assistant Secretary for Fossil Energy, spoke on the role for government in the development of the carbon capture and storage (CCS) industry. He expressed a commitment to CCS and noted that the U.S. government is making demonstrable contributions. He noted a priority to build demonstration projects; one example is the Petra Nova project in Texas.

Discussion:
• One audience member noted that early mover CCS projects are expensive; they are too expensive for industry to undertake alone and government funds have not been sufficient to close the cost gap.
• Another comment addressed carbon capture from natural gas facilities. The commenter noted that most research so far has been on CCS from coal facilities. Two points were made in response. First, the most recent budget proposes programs geared toward CCS for natural gas. Second, aside from some small differences (e.g., more contaminants in the case of coal and less carbon content per unit of energy in the case of natural gas), much of the research is transferable.
Chris Greig, “Pathways to a Carbon Capture Sequestration Industry (The Role for Industry)”

Chris Greig, the University of Queensland, discussed pathways to carbon capture and storage from an industry perspective.

Discussion:

- In the ensuing discussion, there appeared to be general agreement that a blended approach is appropriate, which includes a carbon price to serve as a market signal coupled with government investment in industry-supported CCS projects. BP representatives noted that they employ a modest carbon price internally when making projections for the future.

First Deep Dive: Methane Leakage

Steve Pacala, “Understanding Greenhouse-Gas Impacts of CO₂ and CH₄”

Methane emissions are central to achieve climate goals and also inform the debate over the climate benefit of gas versus coal electricity generation. Uncertainty about natural gas leakage rates has enabled the different sides of the debate to use numbers that support their position. The EDF natural gas leakage studies are unique in that the investigation team included multiple groups that do not usually work together (environmental organizations, industry and academia). This resulted in each group checking each the other’s methods and has led to very robust results about which all of the groups agree.

Steve Hamburg, Chief Scientist, EDF, “Leakage from Natural Gas Production and Distribution”

The EDF natural gas leakage studies include an analysis of leakage rates from the Barnett Shale well fields in Texas. The investigation involves simultaneous top-down and bottom-up estimates, which match well (within 20%).

The large sources can be targeted to cost-effectively reduce emissions. EDF is working with 12 utilities to incorporate these methods into their business. Massachusetts has changed rules to allow accelerated replacement of pipelines to address leaks. A questioner raised the issue of the appropriate timeframe to consider the global warming potential of methane, to which the answer was that there is no scientific reason to favor any timeframe and that it is a judgment call that must be made by policymakers. A small percentage of sources accounts for the majority of emissions.
Measurements of methane leakage from abandoned oil and gas wells in Pennsylvania show that leakage from abandoned wells is a significant source of methane emissions in Pennsylvania. Similar to the EDF studies, it was found that a small number of wells account for the majority of emissions.

**BP Perspectives**

**Felipe Bayon, “BP’s Energy Outlook”**

BP is shifting its focus from purely quantity to also *quality* of its energy production. It envisions that the future (2030) energy mix will be nearly equally divided among natural gas, oil, and coal. Globally, energy intensity is decreasing, and CO₂ emissions have declined by 9%. BP projects that the fastest energy growth will be found in the industry sector and in non-OECD countries. Also, they predict that North America will become a major energy exporter. There is no one silver bullet that will reduce emissions; thus, we need to ensure there are sufficient incentives (such as a carbon price) for the market. In summary, there are (1) continuous changes in the norm of energy markets, such as the recent increase in gas and decrease in coal; 2) changing energy trade patterns, e.g. recent exportation trend from west to east; and 3) changes in the carbon emissions path.

**Paul Jefferies, “Carbon and Climate: Recent Developments and the Year Ahead”**

Because earth’s temperature will rise, Industry, government, and individuals need to act. 2015 is a big year for BP’s carbon policy, with the Paris Conference and the myriad of activities it fosters. Burning all known carbon reserves would lead to catastrophic climate impacts. The challenge is meeting global energy needs for prosperity and economic growth while reducing carbon damage. Many stakeholders need to be engaged. Most of the world’s oil reserves are owned by national governments. BP takes a dynamic and evolutionary approach to carbon management. Crude reserves are typically replaced in a 15-year period. As a proxy, BP uses a carbon price of $40 per ton (above any current price in the U.S.). BP keeps pace with developments in climate science to understand the physical impacts on its infrastructure. Its shareholders have asked BP to do more. Within the World Economic Forum, BP is working on a new initiative, the Oil and Gas Climate Initiative (OGCI). Its work streams address reducing methane leakage, a long-term transition to low carbon fuels, and carbon pricing. BP will report on its best practices, the role of CCS, and access to energy.

**Discussion**
• How do you deal with unburnable carbon? Not all carbon is equal. BP suggests that oil and gas is a part of the energy mix. Diminishing coal in the mix will be good for climate and provide opportunities for other energy sources.

• How do you align incentives with these new objectives? The world has already identified more carbon than it could safely use, yet every individual country has the incentive to continue exploration. We need international cooperation to align the incentives for individual countries.

• How would BP react to a hypothetical renewable energy break-through? BP’s reserves are only committed 13 years in advance, such that if there is a breakthrough in an alternate energy technology, energy investments would allow it to adapt quickly.

Advisory Committee Reflections—Dallas Burtraw, David Hawkins, and Michael Levi

The Committee members spoke highly of the annual meeting and annual report. The annual meetings are an opportunity for exchanging ideas and asking questions of experts to illuminate findings that are not obvious in the scholarly literature. The research works accomplished by the CMI team is informative and can help improve policies in the U.S. and other countries. CMI should use tools such as social media (twitter) or newsletters to publicize its work.

Second Deep Dive “When will carbon emissions peak?”

Ottmar Edenhofer, “The Global Perspective”

The latest IPCC reports show that economic growth was the most important factor contributing to the increase in emissions in the past decade. There has also been an increase in carbon intensity as coal has gained market share and the use of coal will continue to grow unless we intentionally reduce its use. We have not historically seen a country maintain its economic prosperity while reducing emissions; thus there is no historical experience leapfrogging. As for mitigation scenarios to achieve climate goals, without bioenergy combined with CCS, even the three-degree goal is unachievable. A delay in immediate mitigation actions would require more negative emissions between 2030 and 2050, as well as an even more dramatic up-scaling of renewables. Low energy demand can be a hedge against CCS, while the increase in low-carbon technologies is still necessary. In addition, carbon emission reduction does not just mean
decarbonizing the power sector. Efforts in other sectors, e.g. afforestation, are critical too. CCS is one of the most cost effective mitigation strategies. Human beings are not running out of fossil fuels, and therefore the majority of resources have to stay underground if we are going to mitigate successfully. A price on carbon is the only way to reflect the scarcity of displacing space in the air, and can serve as the entry point into climate policy.

Discussion:

• Is the shift from coal to gas in the U.S. replicable in other regions? Reduced coal demand in the U.S. would lead to lower coal prices, which will correspondingly increase coal usage globally. Without a carbon price, additional supply of fossil fuel will end up in an increase in fossil fuel use.

• What are the indirect effects that CCS has on coal markets? If CCS becomes cheaper, more coal can be burned. The main problems are storage capacity and costs. Getting the carbon price right is the first step to encourage investment in CCS.

• BP’s view on carbon tax is that there has been an increasing portion of the oil and gas sector declaring support for a carbon tax. So the bottleneck is the government. For instance, government may prefer hidden regulation to increasing tax in a transparent way. If a carbon tax were to be introduced, it would be regressive and have distributional challenges between classes and countries, which would incur political challenges. However, without a carbon tax, the experiences in Germany have shown that subsidizing the clean energy sector has pushed away gas and has made coal even more attractive.

• Politics is the key constraint, which comes from the public (the median voter). One proposal may be to repay tax revenue to median voters – either through tax reduction or infrastructure. Carbon taxation is an opportunity to do something for the current median taxpayer – it does not have to be to benefit future generations.

• How do the bottom-up climate efforts affect the future of IPCC? There are two potential pathways. IPCC goes back to only studying physical sciences; alternatively, IPCC could partner with complementary international organizations to help national decision-makers.
Zheng Li, “The China Perspective”

China is experiencing changes in many dimensions: a slowed economy and GDP growth rate, the recent air pollution crisis turning into a political issue, a leadership change that may introduce different perspectives to its future reforms, etc. Meanwhile, constraints on carbon emissions have started to appear: China pledges to peak its CO₂ emissions before 2030; natural gas use is increasing while oil use is decreasing; a national carbon market is going to be launched in 2016; the share of clean energy in China’s total consumptions is targeted to reach 20% by 2030, etc.

There are several factors that may influence China’s future emissions. First, half of the coal is used in the power sector, while the other half in steel, cement and chemical industries. Therefore, targeting the power sector is not enough to curb coal consumption and the associated carbon emissions. Second, the natural gas price is still too high to displace coal. Third, there may be a peak in the demand for raw materials that may reduce the demand for coal. Fourth, a reform in the power sector to increase the efficiency of thermal power plants may be low-hanging fruit to reduce emissions. Fifth, electricity transmission is shifting from between neighboring regions to a larger geographic scale. In addition, China has become an important exporter of solar, hydropower and wind power equipment, with an increasing influence on the global energy market.

Discussion:

- The international impact of China’s domestic coal cap – whether it will facilitate the export of coal-related technology and equipment, and encourage China to finance coal projects elsewhere. As China rises in the international community and creates its own institutions to formalize its investment, it may bring new changes to the international coal market.
- One of the U.S. and China partnerships is on CCS. The Clean Energy Research Institute is a partnership mechanism through which the U.S. will transfer technology, mainly the sequestration part, to China. However, the primary issue is costs. The Chinese are reluctant to invest in CCS as coal reserves have capped.
• Is it China’s ambition to become the leader on electric vehicles? 100 million electric bicycles have emerged. The progress to develop electric vehicles is slow, because such progress is tied to the international auto industry.

The U.S. Perspective

Michael Levy: We need to look at how changes in the market environment will affect technology decisions. Some dynamics include the collapse of oil prices. The future oil price is highly uncertain and volatility is also projected to increase. Low prices, uncertain prices, and volatile (known uncertainty) prices all play a role. Additionally, there are income and substitution effects; for example, there is a noticeable trend in increased purchasing of light trucks. Obama’s emissions standards will be up for review in 2017. It is a myth that you can use World Solar Energy Index as an indicator of renewable energy progress and the price of oil.

Dallas Burtraw: One key aspect of the Clean Power Plan is that states have the flexibility to address their target as they see fit. Ten states currently have cap-and-trade and other forms of emissions trading. EPA has several building blocks: expanding the renewable fleet, energy efficiency, and reducing the coal fleet. There is an administrative advantage for states to pursue cap-and-trade. There are different standards in different states, which may or may not introduce leakage. This summer the EPA will unfold its plan regarding non-compliance. The bottom-up coordination approach (and its problems) is analogous to international challenges.

David Hawkins: We could reach a global emissions peak tomorrow. The point is that if we do not substantially reduce our emissions, it does not matter when the peak is. Fossil fuels are too convenient and affordable, so we need policies in order to make any progress in reducing emissions. Some reasons for optimism are found in EIA’s new annual report that projects flat carbon dioxide emissions. Closing their predicted gap does not seem impossible. Leadership by China and India could spur a substantial change in global emissions.
Discussion:

• The Republican Party has become the “carbon party” and Republican leaders’ concern has been driven by the War on Coal. However, conservative politicians might support a carbon tax if it is revenue neutral and goes back to taxpayers via a per capita rebate or the like. Members of Congress do not want to impede the U.S. economy if the international partners are not going to curb their emissions as well.

• Is the price collapse in oil due to geopolitics? The speakers are not convinced that geopolitics is enough of an explanation for the drop oil prices.

Recap: What have we learned?
Terrestrial sinks are more durable than BP had previously thought. It’s very relevant for BP to hear about the role of carbon budgets, carbon pricing, and policy. Uncertainties in the sciences are moving towards resolution. However, there is more uncertainty in how to encourage appropriate policy. We need to think more about how to make a carbon price happen, not just discuss its necessity. A big surprise was the confirmation that we are in the midst of a societal transformation, that BP’s energy outlook points in the opposite direction than IPCC projections. The concept of the Chinese striving for “moderate” living standards as opposed to carbon-intensive living standards is interesting. This conference has taught one speaker that we collectively don’t understand how to solve the problem yet. 2015 will be a big year. As for the partnership within CMI, a good collaboration is a terrible thing to waste. The interaction among us between annual meetings has increased.

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