Summary of a Workshop on Identifying and Avoiding Potential Dead Ends and Missed Opportunities in Climate Policy

February 4-5th, 2016
Revelle Conference Room, AAAS Building
1200 New York Avenue, Washington DC

This workshop was held by the Carnegie Mellon University Center for Climate and Energy Decision Making which is supported through a cooperative agreement between the National Science Foundation and Carnegie Mellon University (SES-0949710). The agenda of the meeting is attached. No effort was made during the workshop to reach consensus conclusions. The following is a summary prepared by the organizers, and may not reflect the views of a number of the participants.

Highlights

- **Major innovation will be essential** if the world is to achieve deep decarbonization of the energy system and the economy. To date the pace if such innovation has been too slow.
- **Low natural gas prices** have created a disincentive for pursuing the needed innovations.
- In addition to low cost, there have been **major air pollution benefits from the switch to gas.**
- The **Clean Power Plan** (CPP) could be expanded more easily to achieve deeper emission reductions if is implemented with a mass-based approach, which is friendly to trading.
- While the CPP is unlikely to stimulate much reduction in CO_2 emissions that would not have taken place anyway, **it *is* stimulating needed interactions** (e.g. between State DEPs and PUCs) and may play an important role in **preventing future backsliding** on emission reductions.
- Absent tighter limits on CO_2 emissions, progress on **carbon capture and sequestration** has stalled and it is unlikely that the CPP alone will rekindle much action.
- The U.S. has significant capacity (**pore space) for deep geological sequestration** of carbon dioxide. However, both social and technical challenges could limit how much of that capacity can be used for CO_2 disposal. Little attention is being given to possible alternatives.
- **Biological systems** might be part of the solution to carbon capture and use but have not received adequate research attention. The same is true of **direct air capture**.
- Achieving a very large share for **renewables** (~80%) will require the energy system to have a much larger footprint on the land, and higher cost, than may be palatable. It might be cheaper to combine low- or zero-carbon baseload power with a less ambitious role for renewables. A large share for renewables might be feasible if a new, continent-spanning HVDC grid could be built.
- Because of low cost gas and the high cost of life extension, **many of today's nuclear power plants will be retired by mid-century,** this despite the fact that many forecasts of future U.S. electricity generation continue to assume that nuclear power will contribute roughly 20% to total electricity generated.
- **Making nuclear viable** as part of a future long-term portfolio of low carbon sources of energy will require moving past light water reactors, which in turn will require substantial government and private investment in basic research and development. Today neither is occurring at the needed level in the US.
- It is likely that in the future achieving **the goal of ≲ 2°C** articulated in Paris **will require negative emissions**.
- Governments reform inefficient **subsidies** in response to a fiscal need, *not* because they discover that they are inefficient. Money freed up through such reforms may not be deployed to support efficient green subsidies.
- Dominant early movers (e.g., the EPA's trading-ready Clean Power Plan; the US-Canada carbon market spearheaded by California; the EU ETS) are likely to shape the characteristics of future markets for carbon, and are putting in place mechanisms that could serve as templates for **expanded international arrangements**.

In the following, rather than keep repeating phrases such as "one participant argued," or "several participants argued," we have often just reported their statements – which may or may not have been widely shared.

Major innovations and substantial investments are needed if we are to achieve deep decarbonization. However, low gas prices are impeding many needed actions and investment.

There is no way that the U.S. and the world will achieve deep decarbonization without major innovations in energy technologies. However, at the moment the low cost of natural gas is a disincentive to investment in the research, development and demonstration needed to achieve these innovations. One obvious example of this is the relative lack of attention to finding ways to deal with the variability and intermittency in output from sources such as wind and solar. We need substantial progress in storage of energy and on managing energy services on both the demand and supply side.

Stimulating the innovations and investments needed for deep decarbonization (net-zero emissions) will require not only a carbon tax or a cap, but also a credible plan to keep ratcheting the tax up or the cap down. In some cases it is likely that performance standards will also be needed and may be more effective in assuring reductions than emission taxes. If key players think they can successfully stall or delay future tightening of policy, progress will be limited.

While low cost gas may be a disadvantage from the perspective of accelerating climate policy (and also lead to increased atmospheric release of methane – a powerful greenhouse gas), one major advantage of the ongoing switch from coal to gas is that conventional air pollution is being reduced. This carries very large health benefits.

The U.S. EPA Clean Power Plan (CPP) is a good first step but there is a risk that it could be implemented in a way that does not easily scale up to much deeper cuts once the initial 32% reduction has been achieved

The Clean Power Plan has sparked conversations about how to decarbonize even in states that oppose the plan. In the past, state environmental agencies have often not communicated with state public utility commissions - the CPP has made those conversations happen. The "water cooler" conversations are more positive, and more sanguine about being able to meet the plan's requirements, than the "podium" conversations.

In terms of incentives for building infrastructure, the Plan does not provide signals that are very different from those that already existed given low gas prices and the need to comply with other environmental regulations. It will not have a big impact on renewables, whose deployment is fueled by targeted subsidies. It will also not drive much in the way of additional emission reductions, but it could serve to prevent backsliding and act as a ratchet.

The incentives not to build new, more efficient natural gas generation are weak – this could produce a sort of technology lock-in for several decades. At the same time, while it is likely that a few coal-heavy states will have to make investments to comply with the CPP, it is unlikely that many power plants will be built that would not otherwise have been built.

The CPP may not lock anything *out* because technologies for deep decarbonization are likely to take longer to be ready for deployment than the planned lifetime of the CPP, which runs to 2032.

The rate-based targets are, in most cases, more onerous than the mass-based ones. EPA has been quite generous with the latter. An exception might be states that have nuclear plants coming online.

The EPA's "trading-ready" template reduces the problems that this will create for states; there will likely be a number of markets, with RGGI states and California retaining their current markets; states that go it alone may end up having their plan rejected and having the Federal, mass-based, trading-friendly plan imposed on them.

One way to prevent the CPP turning into a regulatory dead end is to extend it to include more stationary sources such as cement and smelting. Any expansion to other sources would only work for mass-based plans. The EPA is allowed to review the plans every eight years and could revisit it. Half or more of emissions reductions since 1990 have been due to regulatory tightening; not Congressional action.

The CPP also made possible international engagements such as the US/China climate talks. That said, the inducement for innovation in energy production comes from national goals (e.g., improving air quality) and not in reciprocation to the CPP.

One way to avoid technical or regulatory dead ends is to think of what the next "forcing mechanism" could be to get carbon out of the system. The desire to achieve reduced emissions of mercury helped provide an impetus for a move away from coal, as have low natural gas prices and the Clean Power Plan. What comes next? One participant suggested that a plausible mechanism could be a carbon tax that emerges from a broader attempt at tax reform. There is nothing in the CPP that would preclude a carbon tax.

Any future plan might need to pay off those who stand to lose part of the investments they made in response to the CPP. A concern was raised that some of the assets created by the CPP could be in the form of credits, which may be held by financial institutions – depending on how it was framed it could be politically toxic to pay them off.

While a carbon tax could be an effective way to deal with power plants and other stationary, sources a design standard (CAFE) would continue to be more effective for kick starting decarbonizaton of mobile sources since "a dollar a ton tax on CO_2 is about a penny a gallon at the gas pump" – and a 20-40¢ increase in the price of gasoline will not induce major change.

Are there potential dead ends with respect to future disposal of captured carbon dioxide?

CCS is a potential solution not just for fossil-fired power plants, but also for cement, iron and steel, and even some forms of direct air CO_2 capture.

For deep decarbonization of the electricity system it will not just be necessary to apply CCS to coal plant but also to gas-fired generation. However, DoE research on CCS is being run out of its coal program. Putting resources into CCS for natural gas or industrial sources could involve taking money away from coal, which would be politically fraught.

It is probably neither publicly acceptable, nor technically feasible, to sequester large amount of CO_2 in the oceans by iron fertilization. Indeed any form of "fiddling with the ocean," including disposal of supercritical CO_2 at depth, is probably a political non-starter. Geological sequestration also has technical and public acceptance issues. There are biological routes, but too often we have gone straight to testing solutions without doing enough basic science.

In some cases the problem of induced seismicity can be converted into an administrative one by compensating people. While mostly small scale and experimental, historically CCS programs that have started early with lots of public outreach have been successful.

Wind and solar hold great potential but also hold the potential to lead to "dead ends."

A study was presented that demonstrated how, with a large continental-scale network of DC transmission, a very high (~80%) penetration of wind and solar could be achieved at a cost not very different from current prices. While this proposal met with great interest, concern was

expressed that lack of public acceptance, and land use conflicts, could prevent such a system from being fully built. It was suggested that interstate highway rights-of-way might be used to counter some of these problems – just as rail rights of way were used to facilitate the siting of telegraph and later fiber optic cable.

Managing the consequences of seasonal (and not just day-to-day) variations is difficult and expensive. Some technical questions such as system inertia, and the ability of power electronics to deal well with intermittency remain important and as yet unanswered.

Partly due to the high cost of maintaining a subsidy for renewable generation, and the cost of connecting that generation to the grid, there have been policy turnarounds in a number of jurisdictions (e.g., Germany, UK, Nevada, Spain, Portugal).

Every additional unit of intermittent capacity is likely to be less valuable, and make zero carbon baseload resources less economically attractive (and therefore less likely to be built).

While many energy forecasts continue to assume that ~20% of U.S. electricity will come from nuclear, if current trends continue, most of today's nuclear plants will be retired by mid-century

Most projections of how the U.S. might achieve decarbonization of the electricity system assume that nuclear power will continue to meet ~20% or more of demand. This assumption looks increasingly hard to justify given the rate at which older plants are closing, and that over the next several decades, in parts of the country that have introduced competitive supply markets, construction of new nuclear plants is almost certainly *not* going to occur.

If nuclear and coal are completely phased out by 2050 the US could face a considerable energy shortfall in the electricity supply and would be fully reliant on only two technologies to fill its electricity needs: natural gas and intermittent renewables. In this reading, the failure to innovate and diversify is a national security issue (in that abundant electricity is necessary for economic health, which is necessary for security) as much as an environmental issue.

Conventional Light Water Reactors (LWRs) are unlikely to be a cost effective part of a future generation portfolio for deep decarbonization. However, the R&D needed to develop a superior nuclear generation technology has yet to be commence. Major changes in institutions controlling nuclear power are necessary before we can move past LWR designs

For at least the next several decades the only option the U.S. has for nuclear power is conventional light water reactors. The Nuclear Regulatory Commission is, by design, a highly risk-averse institution. Their regulatory system has expertise in the area of conventional LWRs and its approval processes are a major barrier to innovation towards other nuclear designs. For example, SMR designers have opted to use fuel that is already licensed and stick as close as they can to existing LWR designs. Successful development, deployment and regulation of nuclear power in the second half of the 21st century requires a broader base of expertise and a technologically-neutral regulatory framework.

To move beyond conventional LWR designs the DOE will need to mount a significantly expanded research effort on basic science and technology related to advanced reactor design. In addition to more R&D funding, good leadership and appropriate test environments are needed for new fuels.

Two of the biggest barriers to nuclear are risk premium and efficiency. Light water reactors have 30% thermal efficiency (compared to up to 60% for new combined cycle natural gas). New designs can get around these limitations, but require considerable basic research in fuels and materials and appropriate test facilities. For example, reactors that operated at higher

temperatures and had cores that were more resistant to radiation would operate more efficiently, be need to be refueled less frequently or not at all, and produce less waste.

Creating market pull (e.g., by guaranteeing nuclear power a minimum price) could provide a powerful incentive, but may not do enough to drive innovation. In response to the question of whether a carbon tax would stimulate nuclear, a number of participants argued that such a tax might help keep existing nuclear running in the face of low natural gas prices, but that it would not be sufficient incentive for the development and commercialization of new technologies.

Participants argued that the payback period for inventing, licensing, and constructing an n^{th}-of-a-kind reactor (where $n \gtrsim 8$) is 40 years, and no private player would undertake it without considerable government support at least to do the basic science.

The reason such support is not forthcoming is partially cultural. There is a strong bias towards "shovel-ready" projects: finding something we know how to build, and building it.

Nuclear is likely needed for decarbonization in the developing world, but the DoE is principally interested in preventing proliferation. The US may not lead in the development of new nuclear technologies. A better model might be to partner with other countries that are willing to develop new designs, most likely China. However, the view was also expressed that 1) there are major obstacles with respect to export control and intellectual property and 2) China, South Korea, and Japan have historically been followers.

A view was also expressed that a big barrier to the adoption of nuclear is the dread felt about human exposure to low-level ionizing radiation. Total exposure is measured cumulatively regardless of the time over which it takes place. Some participants argued that this ignores the body's ability to repair itself.

Subsidies can be easy to implement but are often hard to turn off once they are in place.

Many participants believed that government subsidies could be important when learning curves for new low carbon technologies were moderately steep but the cost of a technology was still too high to make it competitive in the market. However, there was also concern that once a technology becomes cost competitive, it can be politically very hard to end a subsidy that is no longer needed.

The German experiment with solar is based on a desire to rid the country of nuclear; not of low-carbon generation. If Germany's solar experiment fails, that could be a big setback for renewables.

The issue of the opportunity cost of renewables was brought up. The argument was that the large subsidies offered to renewable energy might be better directed at innovation in other areas.

A counterargument was made that, while the subsidies for renewables were visible and therefore attracted opprobrium, all sources of energy received tacit subsidies (e.g., Federal tax structure for large capital investments in oil and gas, and liability cap for nuclear). This second set of subsidies was hidden well enough that it did not cause as much concern.

Another flaw in the "opportunity cost" argument is that it assumes that if the money were not given to renewables, it would be given to some other way of producing carbon-free energy. Governments reform subsidies when they need money for something that is deemed more pressing; this may not be related at all to what the subsidy was originally targeted at.

While corn ethanol subsidies were held up as inappropriate, one participant pointed out that, had it not been for them, a market and large infrastructure for producing and transporting ethanol

(which, in the future, could be produced in a way that *did* significantly reduce GHG emissions) would not have existed.

International issues

On the international front, many of the challenges/opportunities/potential dead ends are in developing countries; for example, India could be locking itself into coal.

It seems likely that a few dominant early movers will shape the characteristics of future markets for carbon. For example, the EPA's trading-ready Clean Power Plan is a potential template in the international context as are Post-Westphalian approaches such as participation by Ontario and Quebec in a carbon market with California.

Many approaches (e.g., ones that put cities or states/provinces at the center) have not achieved very much: the Western Climate Initiative has seen its membership swell and then shrink.

While some participants felt that the Paris climate talks had the "wishful thinking" feel of a corporate sustainability initiative, others felt that it fostered a narrative that was supportive of action. This was countered by pointing out that narratives that are wrong or simplistic might do more harm than good.

Closing remarks. At the end of the second day we went around the room asking participants for final thoughts. Here are a few:

- Individual sources of demand and of CO_2 need to become visible/transparent. If we had a set-up that optimized these, then the number of nodes we would be planning for would be very large. We are behind the ball in terms of planning the distribution system.
- There needs to be more discussion about issues of land use and of lock-in in terms of social ecology and institutions.
- The discussion demonstrated the need for long-term R&D policy.
- Visioning is important, because narratives are important in the political environment. At the same time, overly simplistic narratives could create dead-ends of their own.
- Before we build anything, we need a model of which we can ask "what-if" questions, and enough basic knowledge to build one.
- Something that looks like a dead-end policy today might not be in the future.
- We need to devote more attention to what could/will reduce demand.
- How something gets justified may be different from what the initial objectives were – as such, stating objectives vaguely can be a benefit.
- The desire to avoid dead ends has to do with efficiency; but has major infrastructure ever been built without redundancy? Do people care about efficiency if something is seen as an imperative?
- One major argument for efficiency and avoiding dead ends is that there is a time constraint: we need to get to "zero" between 2050 and 2100.
- One way to get around dead ends may be to accept solutions that seem sub-optimal in the short term and add optionality to them.
- Biology will likely need to be part of the solution for achieving deep decarbonization.
- It is difficult to reconcile some of the things that seem necessary with a neoliberal, market-oriented logic
- A lot of the discussion was conducted in the first person plural: "we need to…" However, this assumes that there is a "we" that agrees or can agree on a wide range of things, and that the collective "we" can act. This is problematic: it is important to start saying who needs to do what.

Agenda for Workshop on Identifying and Avoiding Potential Dead Ends and Missed Opportunities in Climate Policy

2016 February 4th-5th

Revelle Conference Room, AAAS Building

1200 New York Avenue, Washington DC

Thursday, Feb 04		
11:30 – 12:30	Light buffet lunch	
12:30 – 12:45	Welcome and introductions	
12:45 – 01:00	Motivation for the workshop and what we hope to accomplish	Granger Morgan
01:00 – 01:30	***Case 1:* The potential for lock-in through the wide use of distributed natural gas - Opening remarks** Since natural gas produces about half as much CO_2 per unit energy output as coal, it has been widely promoted as a potential "bridge fuel" to achieve significant emission reductions in the short term. However, relying heavily on natural gas for decarbonization in the short term could have a number of adverse consequences for achieving deep decarbonization in the long term. For example: • A particularly attractive technology is combined heat and power (CHP) that could significantly increase the efficiency with which input energy is converted to useful electricity, heating and cooling. However if efforts to promote wide adoption of gas-fired CHP were successful, in the future it might become difficult to move on to achieve much deeper emission reductions. • More generally, the availability of cheap gas may squeeze out or postpone investments in forms of zero-carbon energy, such as renewables, grid-scale storage, and advanced nuclear (which we discuss in Case 2).	Jerry Cohon Dan Schrag Steve Hamburg
01:30 – 02:00	Discussion of strategies to move on from the wide use of distributed natural gas to achieve deeper emission reductions. Are there things that could be done now to facilitate a future transition?	
02:00 – 02:30	***Case 2:* The potential to lose existing nuclear power because of low cost gas and institutional factors that create a risk of getting stuck on large LWR designs and not being able to move on to test, develop and deploy more advanced reactor designs - Opening remarks** The boom in low-cost natural gas production, combined with the absence of a price on carbon, is seriously eroding the economic viability of many existing nuclear power plants, and has already contributed to some closures. The situation is further exacerbated by regulatory uncertainties related to plant life extension. If the current political and social climate persists, once these reactors have been taken out of service the prospects of building replacements in the future are poor and the prospects for moving on to more advanced designs may be even poorer. There could also be an erosion of the technical and human resources needed to design, build and operate future plants.	Ashley Finan John Parmentola Ahmed Abdulla
02:30 – 03:00	Discussion of strategies to sustain existing nuclear plants and to assure our ability to move on to develop and deploy new, more advanced, reactor designs.	
03:00 – 03:30	Coffee, tea and light refreshments	

03:30 – 04:00	***Case 3:*** **The risk that the US EPA Clean Power Plan will be implemented in a way that does not easily scale up to much deeper cuts once a 32% reduction has been achieved - Opening remarks** To the extent that the US EPA Clean Power Plan is implemented through a widespread multistate system of emissions trading, it could probably scale up rather easily to achieve deeper emission cuts. However if it is implemented in many individual states with approaches that are not based on trading, it might become much harder to scale up to once the current target of a 32% reduction has been achieved.	Jonas Monast Karen Palmer
04:00 – 04:30	Discussion of strategies that could minimize the risk of lock-in at a 32% reduction	
04:30 – 04:50	Historical insights about the repurposing of long-lived rights-of-way and other infrastructures	Benjamin Schwantes
04:50 – 05:00	Is there is a role for public policy based on real options to add future flexibility when creating real options?	Parth Vaishnav
05:00 – 05:20	Round table discussion on repurposing of long-lived rights-of-way and other infrastructures moderated by Hadi Dowlatabadi	
05:20 – 06:00	General discussion and thoughts from around the table on other topics that warrant consideration	
06:30 – 07:00	Wine and hors d'œuvres at the **Tabard Inn**, 739 N St NW, Washington, DC 20036. Phone: (202) 785-1277	
7:00 onwards	Dinner at the Tabard Inn	
Friday, Feb 05		
08:00 – 08:30	Continental breakfast	
08:30 – 09:00	Recap of Day 1 and comments around the table	
09:00 – 09:45	**Panel discussion: Subsidies, easy to implement, hard to turn off** In order to promote the development of new technologies it is common to offer subsidies. However for political reasons, once a subsidy has existed for some time, interest groups inevitably arise, which makes it very difficult to reduce or terminate such subsidies. One obvious example is the current program in corn ethanol, but there are many others. Which existing subsidies for energy technologies could make it particularly difficult to move on to future lower emission alternatives? What strategies might be adopted to reduce the risk of lock in when such alternatives become available?	Opening remarks by: Mark Kamlet Rush Holt Leah Stokes
09:45 – 10:00	Q&A and discussion of issues related to subsidies	
10:00 – 10:15	**Strategies to reduce emissions from civil aviation and ocean shipping** The International Civil Aviation Organization (ICAO) is considering a proposal to achieve zero net growth in emissions from international aviation after 2020 by requiring airlines to offset any growth in emissions after that. However, the regulation also attempts to achieve a complex set of goals regarding how the obligation to buy offsets is distributed between airlines. The resulting rules are too complex to be easily adapted to achieving deeper cuts and lead to outcomes at odds with the stated objective of the regulation when extrapolated a few decades. In shipping, a performance-based standard for new ships could, in theory, be adapted to produce deep cuts. However, the International Maritime Organization's (IMO) norm of making decisions by consensus precludes agreement on ambitious cuts.	Parth Vaishnav
10:15 – 10:30	Discussion of strategies that could minimize the risk of dead ends and lock-in for regulation of emissions from international air transport and ocean shipping	

10:30 – 11:00	Coffee, tea and light refreshments	
11:00 – 11:30	***Case 4:* Can a heavy focus on wind and solar lead to potential dead ends?** Energy from wind and solar is variable and intermittent. There are a variety of proposals to build future energy systems with high penetrations of these technologies. What are the technical, economic, ecological and social obstacles to the implementation of such systems? Are there ways in which proceeding on a "high renewables" policy, without thinking through how these issues could best be addressed, could result in dead ends?	Steve Brick Sandy MacDonald
11:30 – 12:00	Discussion of potential dead ends related to heavy focus on wind and solar	
12:00 – 12:45	Box lunches and return for discussion around the table	
12:45 – 01:15	***Case 5:* Are there potential dead ends with respect to future disposal of captured carbon dioxide?** Carbon capture technologies on fossil or biomass combustion sources (CCS), as well as technologies to directly scrub CO_2 from the atmosphere, have to do something with the enormous volumes of CO_2 they will produce. Fortunately the US has a large volume of pore space in geologic formations into which that CO_2 might be sequestered. However, a dead end could arise if for technical reasons, such as stimulated earthquakes, and/or reasons of public opposition, we are not able to use much of that pore space for CO_2 disposal.	Ari Patrinos Elizabeth Wilson Howard Herzog
01:15 –01:45	Discussion of how to avoid limitations on deep geologic sequestration and what to do with large volumes of carbon dioxide should either technical or socio/political development limit our ability to do deep geological sequestration	

01:45 – 02:45	Panel discussion of **international issues**: • Is it possible that creative climate initiatives between sub-regions of countries (**"post-Wesphalian" approaches**) are stymied due to existing rules?[1] Should something be done to make the implementation of such approaches easier? Or could such policies themselves result in dead ends? • Assuming that some scalable policy (e.g., a carbon tax or linked cap and trade systems) were put in place in the major developed economies (e.g., US, EU, Japan, Australia), **how could the major developing economies be engaged**?[2]	Leah Stokes Gabriel Chan
02:45 – 03:15	Q&A and discussion of international issues	
03:15 – 04:15	Around the table to all participants for final thoughts, insights and suggestions for next steps	
04:15 – 04:30	Wrap up and end	

[1] For example, suppose that Sweden and California wanted to form a zone in which carbon was taxed at $50 per ton. Such an agreement might require that "imports" from regions not within the zone be taxed based on carbon content. But such a requirement might fall afoul of the Commerce Clause in the US, the EU's rules of free trade, and perhaps WTO rules?

[2] Aspects of the problem that we might want to consider looking at are, for example, (a) How would intellectual property be transferred to, and very likely from, these countries? What barriers could intellectual property issues raise (e.g., concerns about appropriability), and what solutions exist? and (b) How do you deal with the rules of regional trading clubs or bilateral trade agreements that already exist, or might be formed to deal with environmental issues? This is a problem in aviation, because – in addition to the rules of ICAO – air traffic relations between countries are often governed by bilateral agreements, which would not become void even if ICAO rules were changed. So, for example, a nation that wants to impose tax on aviation fuel would have to renegotiate a thicket of bilateral treaties.

Workshop pictures