Towards an Energy Innovation Hub for Carbon Control

The Department of Energy (DoE) has announced their intention of creating a number of Energy Innovation Hubs funded at the level of $25M/year, one of which will focus on Carbon Capture and Storage (CCS). Although the call for proposals is not yet out, the following announcement on the Fossil Energy (FE) website of DoE, gives us some idea of its direction:

"*FE will support the Department of Energy's Energy Innovation Hub for Carbon Capture and Storage. DoE's multi-disciplinary Energy Innovation Hubs focus on critical science and technology for high-risk, high-reward research to revolutionize how the U.S. produces, distributes, and uses energy. Hubs will strengthen the Nation's economy by coordinating teams of experts from multiple fields to blend technology development, engineering design, and energy policy. Finally, they will develop the critical areas of expertise needed for the green economy. In FY 2010, the Energy Innovation Hub for Carbon Capture and Storage will focus on enabling fundamental advances and discovery of novel and revolutionary capture/separation approaches leading to transformational capture technologies to dramatically reduce the energy penalty and costs associated with* CO_2 *capture*."

The capture and subsequent sequestration of greenhouse gases is one of the defining global challenges of this century. No single technology can hope to fulfill all political, geographical, and economic constraints. As such, in the context of a larger Hub, we will include both the more traditional carbon capture and sequestration approaches and additional alternative strategies.

At present the most viable option is to capture CO_2 from power plant flue streams and then sequester it in geological formations. Clearly, it is essential to carry this out as efficiently as possible and to ensure a long-term storage. Our efforts in the two recently funded EFRCs (one on CO_2 capture at UC Berkeley and one on CO_2 storage at LBNL) will focus on these aspects of the problem, and in our proposal for a Hub we will ensure integration and expansion of these ideas.

In addition, we believe that incorporating several creative and perhaps high-risk ideas will be essential to the success of the Hub proposal. A key part of the challenge will be to ensure that such CCS strategies, if successful, could ultimately operate at the enormous scale necessary to have a significant impact on global CO_2 levels. Clearly, fuels are being used at this scale, which suggests that one option would be converting CO_2 into a fuel. In this context, connections with the Helios SERC for solar-powered CO_2-to-fuel conversion and connections with EBI and JBEI in exploring biological greenhouse-gas-to-fuel conversions are desirable. Ideally other creative approaches would transform CO_2 from a material to be passivated into a valuable resource.

Furthermore, development of economical direct-air capture technologies would also be desirable. Direct air capture may be more difficult than capture from a flue stream, given the lower gas concentration, but it offers the possibility of *lowering* greenhouse gas concentrations rather than simply attenuating the growth. A key aspect of direct-air capture would be identifying the greenhouse gases whose removal from the atmosphere would be most impactful on climate change; therefore capture may refer to gases other than CO_2, such as CH_4.

Given the urgency in addressing climate change, another key part of the challenge shall be in enabling rapid adoption of any new technologies develop. We therefore believe that integrating techno-economic modeling and studies of societal perceptions of various approaches into the evolving development of scientific research objectives will help to ensure that any scientific and technological advances will be well positioned for rapid implementation. Additionally, climate

modeling capturing global-scale environmental impacts of various capture and sequestration approaches should also inform the scientific research objectives.

Our ideas are still in the formulative stage, so we would like to receive input from interested participants. We plan to frame the workshop around the following four areas. To get you thinking, we have included some initial thoughts, but we also hope for your creative research ideas that may not fall explicitly within the bounds of the questions posed below.

1. *Chemical Conversions*. Can we chemically convert CO_2 into a fuel, while making efficient use of a renewable energy source? Or can we somehow chemically enhance the rate of carbonate mineral formation for geological sequestration?
2. *Bio-Inspired CCS*. We already have large programs focused on generating biofuels using atmospheric CO_2. Can microbial cellulose-to-biodiesel conversion strategies be adapted to CO_2-to-biodiesel conversion? Are there other lessons to be taken from nature? How does nature ensure selective use of CO_2? Can biomass with long-term stability be generated efficiently and stored?
3. *Physical CCS*. For physical capture from power plants and geological sequestration, how can we best support and enhance the efforts of the EFRCs on this topic? What could the Hub pursue to bridge the gap between the basic research conducted in the EFRCs and industrial adoption of the research findings? Are there other ideas to pursue for physical CCS? Can we directly capture greenhouse gases directly from the air in an economical fashion?
4. *Connecting the technology with the broader context*. How can studies of market feasibility, societal perception, and net environmental impact integrate with and improve an evolving technical research agenda? How can we better understand which technologies are most feasible for fast implementation?

Many interesting approaches are likely to be highly interdisciplinary. For example, envisioning a bio-inspired CCS strategy to have microbes convert light and CO_2 into some high value output like biodiesel directly at the sites of greenhouse gas production, such an end goal would require parallel and interconnected efforts in: (1) constructive biology, seeking to develop microbes that prosper in CO_2-rich and sulfur-rich environments, (2) photosynthesis, seeking to increase the degree to which these microbes can harvest light, (3) engineering, seeking to develop photobioreactors suitable for co-localization with power plants, (4) microbial ecology, since the reactions will be performed by microbial communities, (5) materials science, seeking to develop efficient ways of collecting and distributing appropriate parts of the solar spectrum, and (6) economic modeling and studies of societal perception, to identify the bottlenecks in wide scale adoption of such a process.

In this workshop, for each of the four areas above, we will layout some specifics of the problem and begin to flesh out ideas for the Hub proposal. In order to frame the discussion and facilitate brainstorming, *we ask that participants indicate which area(s) they would be interested in giving a short 2-3 minute single-slide presentation on an idea for the Hub*. Based on the response we will formulate a program for the all-day workshop that will bolster brainstorming and discussion in an interdisciplinary fashion.