Inclusion of Technology Barriers in Economic and Policy Analyses of Greenhouse Gas Mitigation

Barriers to the implementation of carbon management technologies are a potential limiting factor in efforts to reduce greenhouse gas emissions. Barriers include limits to human (e.g. skilled workforce) and material (e.g. natural gas, uranium and rare earth elements) resources, and a wide range of institutional barriers. Barriers that could limit the pace of technology deployment become daunting in the context of the pace at which technologies are envisioned to be deployed to meet goals expressed by governments to reduce greenhouse gas emissions – cuts of 50% or more by 2050. Regulatory frameworks that permit and/or form barriers to technology systems are one type of institutional barrier, and one that was one focus in the 2009 *Workshop on Carbon Management Gaps & Barriers in Electric Power and Transportation Sectors* which was convened by the Engineering Founders Societies' Technologies for Carbon Management project. From that workshop it was concluded:

> *Achieving the proposed goals would entail extraordinary changes in the development and implementation of technology, unprecedented streamlining of regulations to allow these changes, and broad policies that would drive these changes worldwide.*[1]

The clearer inclusion of such barriers -- and the analysis of the effect of addressing such barriers -- in economic and policy analyses has the potential to form a rational basis for actions to address barriers to be considered along-side of actions to develop technologies, and drive technology improvements. To further understanding of such a task, a workshop was held on February 8, 2012 that engaged engineers familiar with technology barriers and researchers involved in the economic modeling of policies to explore *Inclusion of Technology Barriers in Economic and Policy Analyses of Greenhouse Gas Mitigation.*

At the workshop, Engineers with practical experience observed that the timeline for permitting and constructing large projects (e.g. infrastructure and large facilities) spanned over many years. While significant effort has been expended to streamline the deployment of technologies, participants observed that the general trend has been towards longer timelines and more complexity of, for example, the overall permitting process. It was also observed, however, that in exceptional cases timelines can be quite short where all parties are interested in expediting a projects progress. An open question is the degree to which a societal commitment to climate mitigation would constitute such a special case.

At the workshop, researchers involved in modeling the effects of policies on the implementation of technologies and the reduction of greenhouse gas emissions described the ways in which barriers are, or could be, included in their analyses.[2] There are a variety of mechanisms that can be included, however, their global or national analyses

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[1] http://fscarbonmanagement.org/content/gaps-and-barriers

[2] L. Clarke and H. Jacoby, *The Representation of Barriers in Modeling and Scenario Development*.

model deployment of technologies often in a very generic way and better inclusion of barriers would require information on what are the key barriers and quantitative data that would be useful in their parameterization. It was observed that such data was very thin – the foundation for including barriers is, therefore, weak. It was, nevertheless, seen as important as there are examples of current models that do yield results that appear infeasible given today's capacity and resources -- results that are not seen to be realistic.[3] At the same time, it was also observed that many analyses are implicitly based on assumptions about regulatory processes that exist today, and these processes could change dramatically were climate mitigation to become a serious societal priority. Hence, there is ambiguity about whether particular analyses are over- or under-estimating the influence of regulatory barriers on technology deployment.

Many kinds of barriers can be addressed. They can be addressed by, for example, regulatory streamlining or reform, workforce education, and enabling technologies. In the end, addressing these barriers will involve societal decisions to do so. A societal decision to address climate change might influence the degree to which societal decisions are made to address barriers. The extent to which each of these will be addressed is unknown. However, although the goals for greenhouse gas reductions have been stated, their relation to measures to address barriers have not received significant attention.

A natural question that therefore arises is how can we better understand the role of addressing barriers in the context of addressing climate change? Engineers have practical knowledge of the nature of barriers. Researchers have the ability to include barriers and test their potential impact on estimates of future emissions as well as generate projections or scenarios which can be scrutinized to tell if they appear infeasible, or if they would otherwise encounter addressable barriers. Working together, engineers and analysts have the potential to improve understanding on barriers' roles in addressing climate change, and priorities to be addressed with respect to barriers.

A number of early steps could be valuable for bringing together the contributions of engineers and analysts for the examination of barriers.

1. Common scenarios for the change of technology systems that are linked to emissions can be examined and compared to implementation timelines to see whether they are consistent with recent experience, addressable barriers, and the pace at which they would need to be addressed, or whether they are inconsistent with conceivable streamlining and resource availability and, therefore, infeasible.

2. Model results can be unpacked so that investment flows, implementation rates, decision timing, and resource needs can be more easily examined, compared to current barriers and used to identify key barriers for focus.

3. Models do have ways to include barriers, but they are based on very thin data sets. Sensitivity studies could be used to explore how barriers might affect implementation of response options. Sensitivity cases could include those where

[3] L. Clarke and H. Jacoby, *The Representation of Barriers in Modeling and Scenario Development*.

barriers modeled are informed by a) recent experience, b) extension of recent trends (for example of timelines for implementation), or c) of endogenous barrier reduction. Further modeling could identify choke points and key barriers, and quantify their effects on the total mitigation extent or cost, as well as their effect on the choice between technology options – e.g. those that require new infrastructure compared to options where new infrastructure is not needed – which may well depend on location (e.g. nuclear energy in France).

4. Focusing on a few key barriers, data could be gathered, options to address these barriers compiled, and the sensitivity of model projections could be tested.

To advance this work, beginning with the first two steps above is suggested. Questions in moving forward with the first step include identification of the scenarios for focus, communication of their description, and engagement and methods for examination. Following from the first step, a list of metrics could be chosen to be generated by the models for examination in the second step. These steps could also be used to engage people with deeper practical experience in specific to the barriers that appear critical.

The Representation of Barriers in Modeling and Scenario Development

Leon Clarke

Henry Jacoby

Carbon Management Technology Conference

8 February 2012

Pacific Northwest NATIONAL LABORATORY
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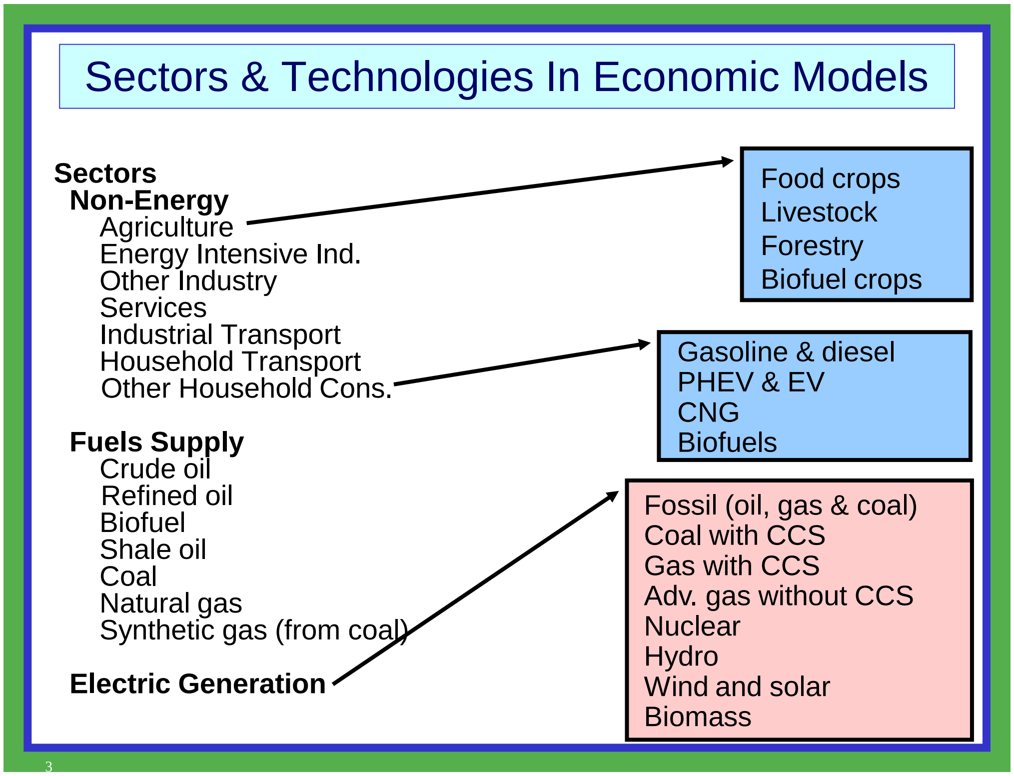
GLOBAL CHANGE MIT

How Modelers View "Barriers"

- Barriers to technology penetration
  - Information
  - Regulatory lag
  - Lack of input suppliers
  - Lack of supporting infrastructure
- Quasi barriers
  - High cost of first installations
  - Rapid expansion raises input cost
- NOT barriers
  - High engineering cost
  - Finance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Sectors
Non-Energy
Agriculture
Energy Intensive Ind.
Other Industry
Services
Industrial Transport
Household Transport
Other Household Cons.
Fuels Supply
Crude oil
Refined oil
Biofuel
Shale oil
Coal
Natural gas
Synthetic gas (from coal)
Electric Generation
Food crops
Livestock
Forestry
Biofuel crops
Gasoline & diesel
PHEV & EV
CNG
Biofuels
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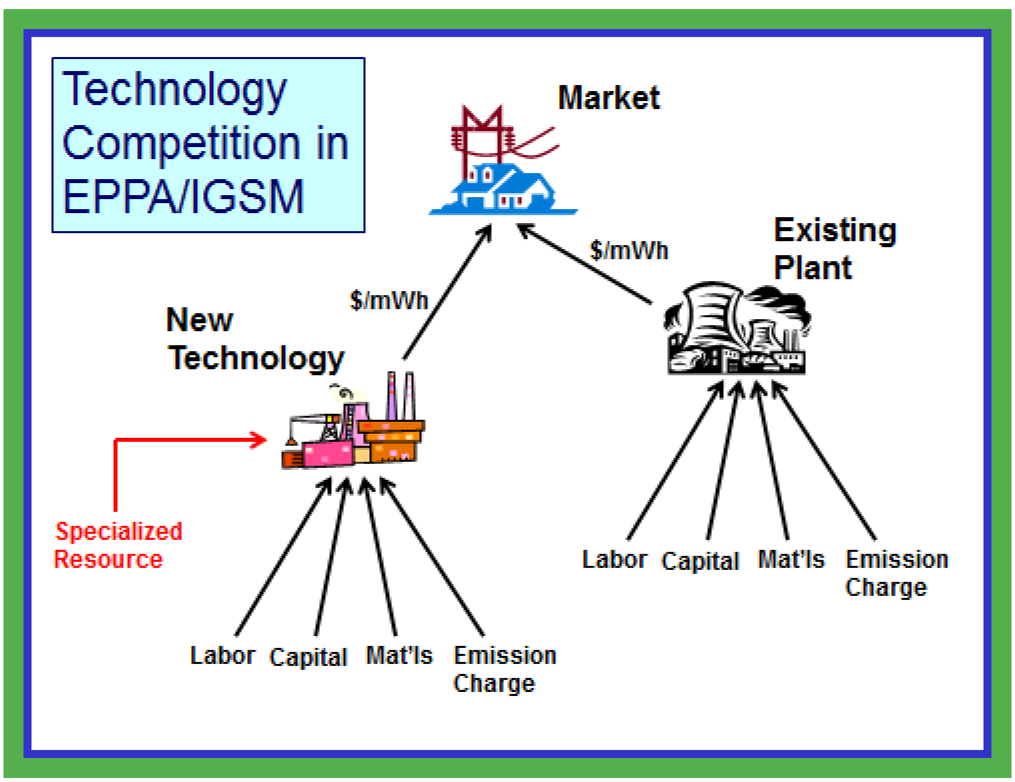
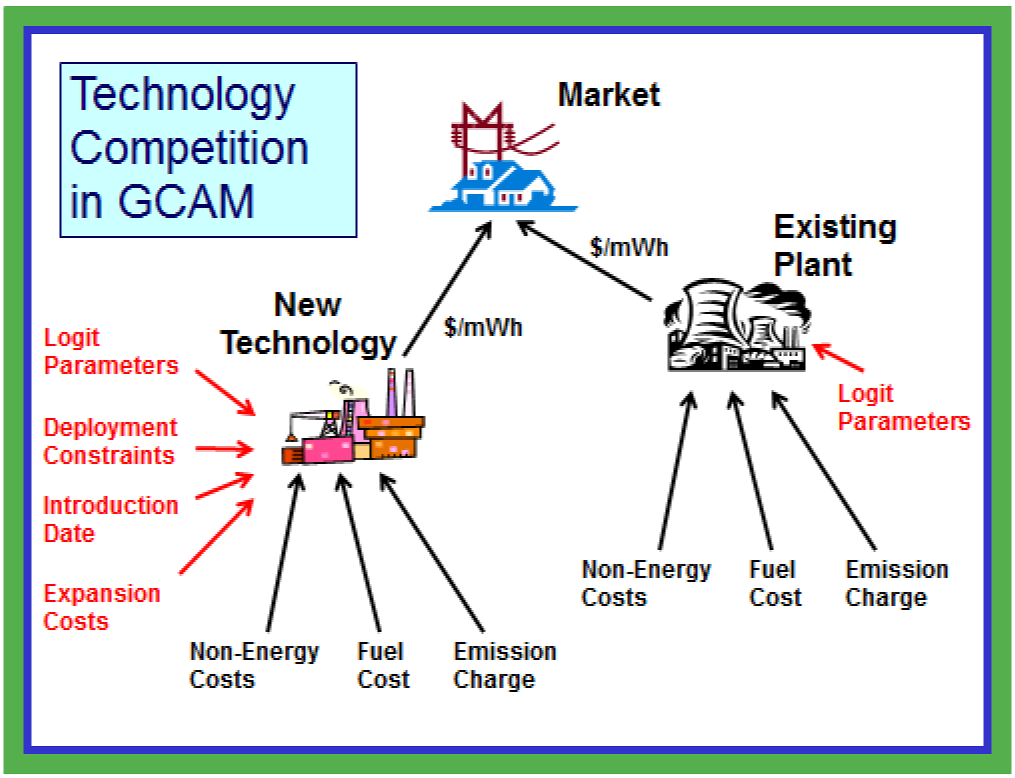

Technology Competition in EPPA/IGSM
Market
$/mWh
$/mWh
Existing Plant
New Technology
Specialized Resource
Labor
Capital
Mat'ls
Emission Charge
Labor
Capital
Mat'ls
Emission Charge

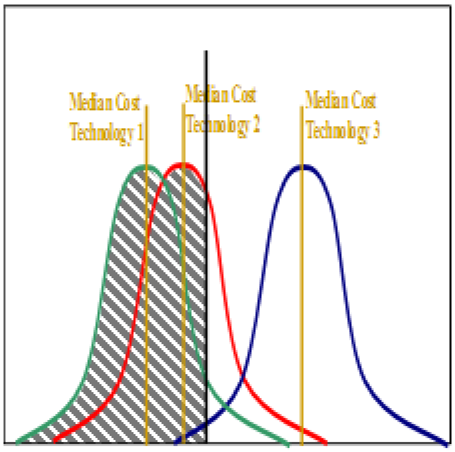
The Importance of Barriers: The Challenge of 450 CO_2-e with Few Barriers (*From Calvin et al., 2009*)

	Not-to-Exceed	Overshoot
Immediate Accession	1) Includes immediate participation by all regions 2) Includes 70% dramatic emissions reductions by 2020 3) Includes substantial transformation of the energy system by 2020, including the construction of 500 new nuclear reactors, and the capture of 20 billion tons of CO2 4) Includes a carbon price of $100/tCO2 globally in 2020 5) Includes a tax on land-use emissions beginning in 2020 6) Includes advanced technologies	1) Includes immediate participation by all regions 2) Includes the construction of 126 new nuclear reactors and the capture of nearly a billion tons of CO2 in 2020 3) Includes negative global emissions by the end of the century, and thus requires broad deployment of bioCCS technologies 4) Carbon prices escalate to $775/tCO2 in 2095 5) Possible without a tax on land-use emissions, but would result in a tripling of carbon taxes and a substantial increase in the cost of meeting the target.
Delayed Accession	X	1) Includes dramatic emissions reductions for Groups 2 and 3 at the time of their accession, 2) Includes negative emissions in Group 1 by 2050 and negative global emissions by the end of the century, and thus requires broad deployment of bioCCS technologies 3) Carbon prices begin at $50/tCO2, and rise to $2000/tCO2 4) Results in significant land-use leakage, where crop production is outsourced to non-participating regions resulting in a substantial increase in land-use change emissions in these regions



An Example "Hook": Logit Share Weights in GCAM

A Probabilistic Approach



The logit formulation calculates the shares of each competing technology

$$s_i = \frac{\alpha_i c_i^{\sigma}}{\sum_j \alpha_j c_j^{\sigma}}$$

Source: Clarke and Edmonds (1993), McFadden (1974)

What is the Path Forward?

- Modelers have the "hooks" to capture factors that will influence the speed at which technologies can be deployed.
- There is a body of knowledge on the factors that influence the speed at which technologies can be deployed.
- What is missing is a link between the factors and the "hooks".
  - We need more research and examples from which to draw model assumptions.