A BRIEFING NOTE FROM THE
DEPARTMENT OF ENGINEERING AND PUBLIC POLICY
CARNEGIE MELLON UNIVERSITY

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Managing Emissions of Carbon Dioxide from Coal-Fired Power Plants

This briefing note discusses four aspects of greenhouse gas (GHG) control in the electric power industry:

- A carbon dioxide price of roughly $35 per ton of CO2 is required before a power plant operator will choose to build a generator that captures carbon.
- Because a carbon price will raise electricity prices, consumers will lower their demand, leading to a reduction in GHG emissions even before new generators with low CO2 emissions are built.
- Renewable portfolio standards are not the same as low carbon performance standards.
- Without significant investment in clean coal technology, the U.S. will be at the mercy of large natural gas exporters in the Middle East and Russia.

Investigators associated with the Department of Engineering and Public Policy at Carnegie Mellon University have performed a variety of studies to determine the cost of alternative strategies that could drastically reduce the emissions of carbon dioxide (CO2) from new and existing coal-fired power plants. In this collection we have reproduced three of these papers:

1. J. Bergerson and L.B. Lave, "Baseload Coal Investment Decisions Under Uncertain Carbon Legislation."*Environmental Science & Technology*, *41*(10), pp. 3431-3436, 2007.
2. P. Reinelt and D. Keith, "Carbon Capture Retrofits and the Cost of Regulatory Uncertainty." *Energy Journal*,*28*(4), pp. 101-127, 2007.
3. D. Patiño-Echeverri, B. Morel, J. Apt and C. Chen, "Should a Coal-Fired Power Plant be Replaced or Retrofitted?" *Environmental Science & Technology*, *41*(23), pp. 7980-7986, 2007.

In considering the impacts of policies designed to limit carbon dioxide emission using either cap and trade or carbon tax strategies, one must address an important question: What price per ton of carbon dioxide must be reached before commercial firms building or operating coal-fired power plants will take major steps to control emissions through the use of carbon capture technology and deep geological sequestration (CCS)? Using three very different analytical approaches, all three of these papers reach the conclusion that the price of carbon dioxide must reach at least $35 per ton before a power plant operator will choose to build a plant with carbon capture (or retrofit a plant with capture technology).

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As they are currently conceived, many proposed cap and trade systems or carbon tax systems will not reach this level for several years. However, it may be sufficient if the policy is designed so that plant operators can see that the price of CO2 will soon reach $35 per ton. Just how soon that price must be reached is also a topic these papers analyze.

Suppose that some mechanism is put in place that imposes a substantial price on CO2 more rapidly than plant operators can change their equipment. That raises costs, and consumers may then buy less electricity. How big a reduction in emissions might that yield? This question is addressed in another recent paper by Carnegie Mellon investigators:

4. A. Newcomer, S.A. Blumsack, J. Apt, L.B. Lave and M.G. Morgan, "Short Run Effects of a Price on CarbonDioxide Emissions from U.S. Electric Generators." *Environmental Science & Technology*, in press.

This paper concludes that in the short-run, before any new generating equipment could be brought on line, the instantaneous imposition of a price of \$35 per metric ton on CO2 emissions would lead to about a 10% reduction in CO2 emissions in PJM and MISO. PJM is the power pool that serves the middle Atlantic Region. MISO is the power pool that serves the upper Mid-West. The price elasticity of demand that leads to this conclusion is -0.1.

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Performance Standards and Carbon Portfolio Standards: Alternatives to CO2 Control Strategies Based on Carbon Taxes or Cap and Trade

Sometimes the perfect can be the enemy of the good. While economists tend to favor economy-wide carbon taxes or cap and trade systems on theoretical grounds, it is important to remember that much of our past environmental progress has been achieved with simple performance standards. For example, California and Washington have both recently implemented a standard that says that any new power plant must not emit more than 1100 lbs of CO2 per thousand kilowatt-hours (MWh) of generated electricity (the amount emitted by modern natural gas generators). For details on the California Standard see www.energy.ca.gov/emission_standards/index.html.

A standard like this has the advantage that it is direct. There is no waiting around for market forces or other social process to respond. The odds of "gaming the system" are also much less. It is possible to write such a standard so that it gradually imposes tighter emission limitations in a predictable way over time so that plant operators who must make decisions about long-lived capital investment can plan accordingly.

While renewable portfolio standards have been very popular, renewables—especially solar photovoltaic (PV)—are often a very expensive way to achieve reductions in CO2 emissions from the power system. An alternative approach that deserves serious consideration is to implement a*carbon portfolio standard* that limits the carbon intensity of all the electricity that a power company delivers to its customers. This idea is further elaborated in:

5. J. Apt, D. Keith and M.G. Morgan, "Promoting Low-Carbon Electricity Production." *Issues in Science and Technology*, *23*(3), pp. 37-43, 2007.

The Risk of Trying to Limit Emissions without Developing New Technology

There is a growing risk that the U.S. or specific states may enact policy to limit emissions without also taking steps to help speed the development of new low emission technology. This risk is especially great for the case of coal-fired power plants. Today the U.S. makes just over 50% of its electricity from coal. While improved efficiency, renewables and perhaps new nuclear power can all help, it is hard to see how they can meet all future need. Unless the U.S. adopts major new policy initiatives to rapidly develop coal technology with CCS, we could see several years of growing dependency on natural gas imported as LNG from the Middle East. An explanation of why that that would be a bad outcome for the U.S., both in terms of energy policy and national security, is provided in:

6. M.G. Morgan, "Needed: A Few New Coal Plants." Editorial. *Environmental Science & Technology*, *42*(3), p. 647, 2008.

The IECM Models

Much of the quantitative policy analysis we do at Carnegie Mellon builds on results from a family of advanced Integrated Environmental Control Models (ICEM) for coal and gas power plants that have been built by Professor Edward Rubin, his students and colleagues, with support from the U.S. Department of Energy. A summary of that work is provided in the papers:

7. E.S. Rubin, A.B. Rao, and C. Chen, "Cost and Performance of Fossil Fuel Power Plants with CO2 Capture and Storage." *Energy Policy, 35,* pp. 4444–4454, 2007.
8. E.S. Rubin, S. Yeh, M. Antes, M. Berkenpas and J. Davison, "Use of Experience Curves to Estimate the Future Cost of Power Plants with CO2 Capture." *International Journal of Greenhouse Gas Control, 1*, Elsevier, pp. 188-197, 2007.

The IECM models are sophisticated stochastic simulation models that use a combination of detailed engineering modeling and the judgments of leading technical experts to yield cost and performance estimates in the form of probability distributions (essentially betting odds on how the technologies will perform). They are currently being used by over 1,000 companies, consultants and policy analysts all over the world.

Many of the ICEM models can be downloaded from the web at http://www.iecm-online.com/.

To request a copy of the papers
contained within this report, contact
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