POLICY: CLIMATE

A Road Map for U.S. Carbon Reductions

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Upon ratification, the climate treaty negotiated in Kyoto, Japan, last month would require the United States to reduce its emissions of greenhouse gases below 1990 levels by 2008 to 2012. Because most anthropogenic greenhouse gas emissions (particularly CO_2) come from energy production and use, this agreement has the potential to affect the entire fabric of society. Here we discuss the technology required to meet this goal, and we outline how the nation could achieve low-cost carbon reductions in the four energy-intensive sectors of the economy—utilities, buildings, transportation, and industry. Our discussion is based in large part on a recent study for the Department of Energy (DOE) by five national laboratories (*1*), which provides a carbon reduction road map for the nation.

A reduction in emissions of about 400 million metric tons (mt) of carbon per year would be required to stabilize U.S. emissions in 2010 at 1990 levels (*2*). The Kyoto treaty calls on the United States to reduce emissions of six greenhouse gases, including CO_2, by 7% below 1990 levels but also gives credit for carbon sinks (for example, reforestation), so that the true target for energy-related carbon emissions may actually be just a few percent below 1990 levels. Not all of these reductions will have to be met domestically, however, because the Kyoto agreement allows the United States credit for reductions through international trading of carbon permits with developed countries and through climate mitigation projects with developing countries.

Nonetheless, substantial domestic reductions will be required, and achieving these will necessitate an aggressive set of policies. The new study (*1*) documented the need for a price incentive to motivate sufficient carbon emission reductions. The laboratories assessed the impacts of a national emissions trading system for carbon, similar in principle to the system established for SO_x, because it is an efficient approach and was a key element of the U.S. position in Kyoto. By assuming permit prices of \$25 and \$50 per mt of carbon, the scenarios analyzed U.S. climate goals (*3*). Firms would be given credit for acting before the trading system begins. To be most effective, the emissions trading system needs to be combined with a technology strategy to develop and deploy energy-efficient and low-carbon technology that varies by sector.

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Utilities

In the energy supply sector, the permit-trading system is the most important policy because it will promote the use of low-carbon fuels. With carbon emissions permits costing \$25 to \$50 per ton, a variety of supply options become cost-competitive. Among them is the replacement of coal with natural gas in some power plants through the repowering of existing plants, retirement of older coal plants, construction of new gas turbine and combined cycle plants, and increased dispatch of gas-fired plants. Carbon trading could also lead to substantial growth in the use of wind power, co-firing of coal power plants with biomass, increases in the efficiency of existing plants, extension of nuclear power-plant life, and expansion of hydropower.

For a carbon permit price of \$25 per ton, we estimate that reductions could be 50 mt of carbon per year in 2010 (8% of forecasted utility emissions); at \$50 a ton, reductions could be 135 mt of carbon per year (22%). To achieve such reductions, the federal government should also expand R&D in renewable energy and advanced fossil fuel technologies, provide targeted tax and financial incentives for new zero-carbon technologies, expand programs to increase the supply of low-cost natural gas, and develop technologies to extend the operating lifetimes of existing nuclear plants.

Carbon reductions also could be fostered by the passage of legislation to deregulate electric utilities that supports investments in increasing the efficiency of existing power plants, promotes greater use of renewable energy technologies, and increases cogeneration (the simultaneous generation of heat and power). Federal or state legislation that supports the continuation of funding for end-use efficiency programs, such as those that many utilities have implemented in the past decade, could be instrumental.

Industry

The industrial sector can contribute substantially to carbon reductions, ranging in our study from 55 to 95 mt of carbon per year in 2010 (or 10 to 17% of the forecasted industrial emissions in that year) (*4*). These reductions can be achieved only if industry directs about 3% of its annual investment in manufacturing to cost-effective energy efficiency and low-carbon technologies. Much of this may be achieved through voluntary agreements between industry and government, but domestic trading of carbon will also be important. Federal and state governments should continue environmental regulatory reinvention that encourages industry to invest in pollution prevention technologies while lowering industry's overall compliance costs. For instance, substantial carbon reductions could be achieved if implementation of the Clean Air Act were to focus on outputs and performance standards and allow credits for end-use efficiency. Financial incentives for clean technologies also need to be considered.

To achieve the efficiency savings, it will also be necessary to expand DOE's R&D partnerships with the nation's most energy-intensive industries, which include forest products, chemicals, and metals. These industries account for 80% of industrial carbon emissions. Accelerated implementation of these partnerships could reduce carbon emissions while abating pollution, increasing productivity, and strengthening global competitiveness.

Encouraging the use of combined heat and power will be essential for transformation of the present centralized electricity grid, consisting of fossil fuel plants that average 34% efficiency, into a system that exploits the 80 to 90% efficiencies potentially achievable by using the waste heat in industrial processes. Capturing the large savings potential of combined heat and power will require continued efforts to deregulate utilities, accelerated environmental permitting, and targeted tax incentives.

Buildings

Reductions of 45 to 60 mt of carbon could be captured from buildings by 2010 (or a 7 to 10% reduction relative to this sector's forecasted emissions). This will require that the market share of cost-effective energy-efficient equipment and appliances substantially increase. Improving the thermal performance of new and existing building envelopes will also be necessary.

Much of the savings in this sector can be captured through the existing authority of the federal government to issue consensus-based standards for equipment and appliance efficiency. Substantial savings can also be achieved by expanding voluntary programs, such as the joint Environmental Protection Agency–DOE Energy Star labeling program. Energy Star labeling has already saved substantial energy in a number of markets, including computers, and is now being extended to windows, washing machines, televisions, and other products. Tax incentives for purchasing super-efficient equipment and innovative financing for efficiency retrofits would spur further efficiency.

Many of the opportunities for decreasing the intensity of energy use in buildings have resulted from past public-private R&D partnerships. Examples include the development of low-emissivity windows, efficient refrigerator compressors, and electronic ballasts (5). Deserving particular attention for achieving 2010 goals are the so-called "miscellaneous energy uses," consisting of many small appliances that often draw current when not actively used. These loads are growing rapidly in both residential and commercial buildings. Other key areas for near-term R&D and deployment include advanced lighting systems; intelligent technology to analyze, monitor, and control operations of commercial buildings; integrated building equipment and appliance systems; next-generation wall and window systems; and reflective roof coatings.

Transportation

Future carbon emissions in the transportation sector depend heavily on whether recent rates of increase in vehicle weight, horsepower, and miles traveled continue. Forecasts of carbon reductions in this sector are also uncertain because they are highly reliant on the development and introduction of advanced technology; the U.S. transportation system could be transformed dramatically over the next decade if certain technological breakthroughs were to occur.

Energy-efficient and low-carbon technologies in this sector could produce carbon savings of 90 to 105 mtC in 2010 (or approximately a 15% reduction relative to this sector's forecasted emissions in 2010). Such savings would occur if the average fuel economy of new cars were 38 to 43 miles per gallon (mpg) in 2010 (increased from the present 27.5 mpg), if new light trucks achieved 27 to 31 mpg (up from 20.5 mpg), if heavy trucks achieved 10 mpg (up from 7 to 8 mpg), and if cellulosic ethanol used as a blending component for gasoline achieved a 3 to 5% market share. Federal R&D has substantially reduced the cost of ethanol from cellulosic waste (such as crop waste) and dedicated crops (such as switchgrass), and continued R&D is expected to allow an ethanol-gasoline blend to be cost-competitive before 2010.

Achieving these goals will require a substantially expanded R&D effort in advanced automotive technologies. The primary R&D effort, called the Partnership for a New Generation of Vehicles, is developing a generation of cars that will be three times as efficient as current vehicles with no compromises in size, safety, comfort, or cost. A variety of efficient technologies such as hybrid vehicle design; advanced engines, including fuel cells and clean diesels; power electronics; regenerative braking; and lightweight materials are under development.

The reductions in carbon emissions also require major efforts to gain acceptance of new technology in the market. Policies that could accelerate the penetration of fuel-efficient technologies include tax incentives for early purchasers of high-efficiency vehicles and other means to provide up-front incentives for the purchase of energy-efficient vehicles. The carbon trading system needs to be designed to provide incentives for automakers to manufacture and sell efficient vehicles. This is the one sector of the economy that is most susceptible to influence from foreign competition; the probable introduction of high-efficiency vehicles by non–U.S. manufacturers in the next decade may itself spur overall gains in vehicle efficiency.

Costs

Under the assumptions that produced the greatest carbon reductions, the study concluded that the direct costs and benefits were comparable: The overall magnitude of direct investment costs ranged from $50 to $90 billion per year, with energy savings of equal or greater magnitude (6). These results can be compared with those of other engineering studies of technological opportunities for reducing carbon emissions. In a recent survey (7), five studies with comparable forecast years and carbon reductions yielded economic costs as a percentage of gross national product ranging from –0.2%, to +0.5% (or a benefit of $20 billion to a cost of $50 billion per year for a $10-trillion economy).

In addition to the direct costs, there are important indirect costs and benefits that neither the new assessment nor most other studies have evaluated. The low-carbon scenarios have winners and losers. On the positive side, air quality will improve substantially. On the other hand, the reduction in demand for coal will adversely affect the coal and railroad industries. Programs to reduce or mitigate these impacts will be necessary.

The price of $50 per mt of carbon for permits, although not constituting a direct cost to the nation, does represent a potentially large transfer payment. The magnitude of the transfer and its winners and losers depend on the nature and implementation of the mechanism for trading carbon.

There are uncertainties inherent in these scenarios. It is possible that businesses and consumers will not invest in existing technologies that can cost-effectively reduce carbon emissions and energy bills. Emerging technologies may not prove as cost-effective as we anticipate. And the policies we describe may face political obstacles.

Conclusion

The targets in the Kyoto agreement represent a great challenge. We have identified technologies with potential for widespread application whose implementation can greatly facilitate the attainment of such a goal at low cost, while maintaining or improving levels of energy services. By using such technologies, in combination with international carbon trading, Americans will not have to reduce their travel, turn down their thermostats, or decrease their manufacturing output to meet the nation's carbon reduction goal.

References and Notes

1. Interlaboratory Working Group, *Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy-Efficient and Low-Carbon Technologies by 2010 and Beyond* [Lawrence Berkeley National Laboratory (LBNL), Berkeley, CA, and Oak Ridge National Laboratory (ORNL), Oak Ridge, TN, September, 1997 (LBNL-40533 and ORNL/CON-444)]. Available at www.ornl.gov/ORNL/Energy_Eff/CON444 or http://eande.lbl.gov/EE.html.
2. Recent results of a new forecast by the Energy Information Administration (EIA) suggest that larger carbon reductions are needed in 2010 to achieve 1990 levels [*Annual Energy Outlook 1998* (EIA, U.S. DOE, Washington, DC, December 1997)]. This new forecast does not substantially change the results discussed here.
3. Fifty dollars per mt of carbon corresponds to 12.5 cents per gallon of gasoline or 0.5 cents per kilowatt-hour (kWh) for electricity produced from natural gas at 53% efficiency (or 1.3 cents per kWh for coal at 34% efficiency). Depending on the nature of the trading system for carbon permits, the consumer may see only a portion of these charges.
4. The carbon saved by improved efficiencies in the use of electricity in industry and buildings depends on the carbon intensity of the electricity avoided. The analysis apportioned the savings between end use and electricity supply.
5. Secretary of Energy Advisory Board, *Energy R&D: Shaping Our Nation's Future in a Competitive World* (U.S. DOE, Washington, DC, 1995).
6. The lower estimates of costs and energy savings used discount rates ranging from 7% (for buildings) to 12.5% (for industry) and assumed that program costs were 15% of savings for voluntary savings and 1% for policies (such as appliance standards). The higher bound assumed discount rates between 15 and 20% and double the program costs.
7. M. Jaccard and W. D. Montgomery, *Energy Policy* **24**, 889 (1996).