

THE COSTS OF REDUCING CARBON EMISSIONS

An Examination of Administration Forecasts

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Executive Summary

How much will it cost the United States to comply with the Kyoto protocol? The estimates range from over 4 percent of gross domestic product and \$348 for the right to emit a ton of "greenhouse gases" to only .1 percent of GDP and \$14 for the right to emit a ton of gases.

In the lowest cost scenarios, U.S. emitters purchase rights to emit from other countries. In the highest cost scenarios, actual U.S. emissions have to be reduced by about 30 percent from what they otherwise would be. Such a cut-back would imply a massive shift from coal- to natural-gas-fired electricity generation. But even the low-cost scenarios are excessively expensive because models of the atmosphere predict that very little warming would be prevented.

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In December 1997, at the third conference of the parties to the United Nations Framework Convention on Climate Change in Kyoto, Japan, delegates from approximately 160 countries, including the United States, agreed to reduce "greenhouse gas" emissions by an average of 5.2 percent from 1990 levels during the years 2008-12. The reduction assigned to the United States was 7 percent below 1990 levels.

Since the Kyoto protocol was signed, numerous estimates of the costs of compliance with its provisions have been issued. For the year 2010, the estimates range from over 4 percent of gross domestic product and \$348 for the right to emit a ton of carbon to only .1 percent of GDP and \$14 for the right to emit a ton of carbon.¹ The estimates vary so much because the underlying assumptions of the economic models used to generate the estimates vary a great deal.

In the lowest cost scenarios, the United States does not actually reduce its own emissions very much. Instead, U.S. emitters purchase low-cost rights to emit from other countries. In the highest cost scenarios, actual U.S. emissions have to be reduced by about 30 percent from what they otherwise would be.² Because coal combustion is so CO₂-emissions intensive, such a cutback would imply a massive shift from coal- to natural-gas-fired electricity generation in the United States. The shorter the time frame over which this shift must occur, the more costly it is likely to be. If cheap existing coal plants are allowed to produce electricity until the end of their economic lives and are then replaced with natural-gas plants, the costs will be much lower. But even the low-cost scenarios seem to have costs that are greater than the benefits, which are mostly symbolic, because models of the atmosphere predict that very little warming would be prevented.

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The CEA Study

In July 1998 the Council of Economic Advisers issued its analysis of compliance costs.³ The council found that compliance would be relatively cheap because we would not actually cut back emissions very much in the United States.⁴

The belief that the United States could reduce carbon emissions cheaply through rapid adoption of alternative technologies, a strategy favored by federal energy laboratories,⁵ environmentalists, and the Clinton administration, is not the basis for the low costs in the CEA scenario. Instead, we would purchase the right to emit greenhouse gases from other countries (primarily the former Soviet Union) that would not be emitting as many greenhouse gases as they are entitled to emit under the quotas allocated by the Kyoto protocol.

The availability of surplus emission capacity in the former Soviet Union stems from the use of 1990 as the base year from which each country's emission reduction obligation is calculated. Soviet industry had not yet collapsed in 1990 and emitted much CO₂ because Soviet industrial boilers and electric generators burned coal rather than oil or natural gas and coal emits more CO₂ than oil or natural gas.⁶

Under the Kyoto protocol, 40 industrialized countries have been assigned carbon-emission quotas relative to their 1990 emission levels.⁷ If the European Union allows trading of its countries' quotas only within Europe, a position currently favored by the EU, then the price of permits supplied by the former Soviet Union will fall, reflecting the lack of European demand for them.⁸ The CEA estimates that under such a scenario, the costs of compliance with the Kyoto protocol would be very low: around \$14 per ton of carbon emissions, an increase in the price of gasoline of about 4 to 6 cents per gallon, and a total cost to the economy of .1 percent of GDP.⁹ If trading is allowed among all Annex I countries and European countries can bid for unused carbon-emission rights from Russia, the price per ton of carbon emissions will be higher: approximately \$61 per ton.¹⁰

The EIA Study

The most pessimistic estimate of the costs of compliance with the Kyoto accord for the year 2010 comes from the Energy Information Administration, an independent governmental agency that gathers and disseminates data about energy

markets. The EIA estimates that the worst-case scenario, in which no trading of carbon-emission permits across countries is allowed (and the United States has to reduce emissions to 7 percent below 1990 levels rather than buy permits to emit), would result in a price for carbon emissions of \$348 per ton, an increase in the price of gasoline of 66 cents per gallon, and a total cost to the economy of 4.2 percent of GDP.¹¹

The EIA and CEA estimates differ because they model completely different scenarios. But even if different economic models are used to predict the cost of nearly identical carbon-emission scenarios, the results can differ substantially. For example, if the United States reduces carbon emissions domestically by the full amount required under the Kyoto protocol without any international trading, the EIA model predicts that the cost of a permit to emit one ton of carbon will be \$348. The model used by the CEA estimates that, without international trading, the cost of a permit to emit one ton of carbon will be \$193, a little more than half the EIA estimate.¹²

Why Do Models Produce Different Estimates?

Why do the estimates of different models vary so much even when they model the same scenario? The economic models, while technically quite complex, calculate their results through four conceptually straightforward tasks:

- Generate an estimate of the level of economic activity in the year 2010 in the absence of any policy changes.
- Predict the level of carbon emissions in 2010.
- Calculate the cost of reducing carbon emissions to their level in 1990 minus 7 percent as required by the Kyoto protocol.
- Calculate the cost of reducing carbon emissions by lesser amounts and purchasing the right to emit the remainder from countries that emit less than their quotas.

Thus the differences in predictions must arise from differences in the four tasks. The models differ in their predictions about expected GDP and carbon emissions in the absence of any policy changes.¹³ But the models differ

even more on how costly it would be to reduce carbon emissions by a given amount. The cost differences stem from

- differences in predictions about the ease of transition from coal-fired to natural-gas-generated electricity,
- differences in the rate at which energy efficiency increases autonomously,¹⁴
- differences in how energy costs translate into costs in other sectors of the economy, and
- differences in how much consumers factor future prices into current decisions.

The optimistic model used by the administration assumes that electricity producers respond very rapidly to carbon permit prices. Existing coal-fired plants are carbon-emission intensive. Thus, if they shut down and are easily replaced by natural-gas plants at low cost, complying with the Kyoto protocol is not economically costly.¹⁵ Other models assume that the transition from coal to natural gas will be slower and more costly. If coal-fired electricity persists, then reductions in carbon emissions must come from sectors of the economy other than electricity, transportation, for example. And since petroleum combustion is less carbon-emission intensive than burning coal, the consumption cuts and hence the permit price required to achieve a given level of carbon-emission reduction are greater than if the cuts come from coal-fired electricity.

The differences in the estimates of the ease of transition from coal-fired to natural-gas-fired electricity and in the rate at which autonomous energy efficiency increases have important effects on the estimates of the costs of complying with the Kyoto protocol. For example, Charles River Associates estimates that in 2010 the cost of reducing carbon emissions to 1990 levels would result in a carbon permit price of \$142 per ton of carbon emissions. To obtain the administration's predicted permit price of approximately \$108 to \$109 per ton, the assumptions in the Charles River model about the transition from coal to natural gas must be drastically modified.¹⁶ The sensitivity of consumers to the price of coal (and the cost of permits to burn it) normally used in the CRA model must triple in magnitude to obtain the administration's result.

The administration's results flow from the assumption that when the total costs of a new gas-fired power plant

fall below the present value of the operating costs of an existing coal-fired power plant, the coal plant is scrapped and replaced with gas, a reasonable and standard economic assumption. The less credible assumption is that all existing coal-fired capacity could be switched by 2010 with no changes in natural-gas, steel, and labor costs or land use and other permitting processes.¹⁷

Other important differences exist between the models. The optimistic models assess only the direct costs to the energy sector of complying with the Kyoto protocol. Other sectors of the economy are assumed to adjust costlessly and instantaneously.¹⁸ Fiscal and monetary policy is assumed to adjust to maintain full utilization of resources in the rest of the economy.¹⁹ In addition, consumers have perfect foresight in the optimistic models.

The less optimistic models, like the EIA model, assume that the adjustments will not be smooth and costless and that residential consumers will not have perfect foresight.²⁰ In addition, the EIA model does not calculate the benefits of permit trading directly. Instead it only estimates the willingness of the United States to pay for reduction (based on our marginal costs). If other countries sell us permits to emit at a lower price than our costs of emissions reduction, the EIA cost estimates are too pessimistic.²¹

Do markets adjust quickly and costlessly or slowly and expensively? The answer varies across markets and depends on the time involved. Financial markets change most quickly with the least stickiness in behavior. Labor markets react much more slowly to demand and supply shocks.²² The natural-gas market is very nimble, but land-use decisions, because they are often politicized through the zoning process, are notoriously slow to respond to changes in relative prices.

The lack of an explicit model of international trade in the EIA model leads to costly estimates of compliance. In any market trade, the consumer has a maximum willingness to pay for a product and the seller has a minimum price he is willing to accept. The difference is called the surplus, or "gains to trade." The division of the gains between seller and consumer is a byproduct of the workings of the market and is not consciously controlled by any of the participants.

In the EIA representation of international trading of permits, the permit price represents the maximum willingness of U.S. fossil-fuel users to pay for permits; that willingness is based on the costs of U.S. compliance if we had to reduce our own emissions. At the limit, we would be willing to pay as much for a permit as it would cost us to reduce our emissions by the amount allowed by the permit. In such a trade the U.S. buyer would get none of the gains to trade.

Instead, all the surplus would go to the international sellers. Such trades are possible, but unlikely, unless all the foreign sellers of permits collude to restrict competition among themselves. Thus the EIA permit price estimates represent a situation in which the countries of the former Soviet Union (the likely sellers of permits) extract all the surplus from trades because of their monopoly power.

Scientific vs. Empirical Validity of the Models

How should we evaluate the various scenarios in the models? First, economic models are simply a series of If-Then relationships. As long as the mathematical links between the "Ifs" and the "Thens" are algebraically true, the predictions of the model are scientifically accurate.

All the models used in estimating the costs of compliance with the Kyoto protocol are scientifically accurate. But the relevance (rather than the scientific validity) of the predictions depends on the plausibility of the assumptions (the "Ifs"). Both the highest and the lowest cost scenarios rely on assumptions about situations that are unlikely to occur.

The high-cost scenarios require the United States to reduce emissions to 1990 levels minus 7 percent on its own.

The cutback of approximately 550 million metric tons of carbon emissions per year (approximately a 31 percent cut from projected emissions in 2010) would require a massive shutdown of coal-fired electricity capacity and a shift to natural gas by 2010.²³ Such a shift is not unprecedented²⁴ but would exceed our recent experience in natural-gas plant construction. Since 1983 an annual average of 10 gigawatts (that is 10 billion watts) of natural-gas-fired electric generation capacity (33 typical plants) has been added. In the scenario in which the United States has to reduce emissions to 3 percent below 1990 levels, 24 gigawatts of natural-gas-fired electric generation capacity (93 typical plants) would have to be added annually from 2008 to 2020.²⁵ The new plants would have to be built on the sites of existing power plants to take advantage of the configura-

tion of the existing transmission system. Conversion of existing coal plants to gas would be cheap but thermally inefficient.²⁶

The importance of the high-cost scenario is not that it is likely to occur. Rather it demonstrates that carbon-emissions reduction without a trading scheme would have a large negative impact on the production of coal-fired electricity and require a massive investment in electricity produced from natural gas. Those two changes are likely to generate political disputes involving coal unions and producers and railroads (which would lose from a quarter to over a third of their revenue) and about the siting of natural-gas plants.²⁷ The political disputes make the costs of compliance with the Kyoto protocol higher than a strict economic analysis would suggest.

The lowest cost scenarios rely on international trading, flexible markets, and rational consumer behavior all occurring by 2010.²⁸ The importance of the low-cost scenario is not that it is likely to happen but rather that smooth and rapid responses to changes in prices and general market flexibility are essential to cost minimization. Consumer and institutional rigidities raise the costs of compliance.

A more likely scenario than either the absence of trading or complete worldwide trading is trading limited to Annex I countries and some rigidities in the responses of firms and consumers to higher prices in the short run. Under a full Annex I country trading regime, the price per ton for carbon emissions is predicted by all the models (except that of the CEA) to be in the range of \$100 to \$130. The GDP losses are predicted to range from .4 to 1.7 percent.²⁹

How much confidence should we have in the economic predictions just described? If experience is any guide, they should be discounted. The use of large-scale models to predict the future costs of policy options does not have a very good track record. In 1975 Resources for the Future, an organization respected for its economic analyses, projected that the total costs of nuclear plants in 1985-88 would be less than the total costs of equivalent coal plants. A set of costly nuclear plants came online during the early 1980s, however, and electricity rates rose 60 percent from 1978 to 1982. By 1990 nuclear plants had total costs that were about double those for coal plants.³⁰ In its study of the energy crisis in the 1970s, the Ford Foun-

dation used a doubling of real (inflation-adjusted) oil prices from 1979 to 2000 in its models.³¹ And many prominent Carter administration officials and economists, including James Schlesinger, Arthur Okun, and Richard Cooper, stated publicly that, at current prices, oil reserves would be gone by the 1980s.³² Even as late as 1983, the World Bank predicted that the mid-1990s oil price would be \$64 a barrel.³³ The actual price of oil in inflation-adjusted dollars in mid-1998 was less than half its 1979 price.³⁴

Conclusion

The political struggle over U.S. compliance with the Kyoto protocol is really a fight about the future of the coal-fired generation of electricity.³⁵ How costly would it be to eliminate coal-fired electricity generation and switch to natural gas?

If we have to reduce drastically coal use in the United States by 2010, the costs are likely to be high even if we consider only economic factors. Given the likely political resistance of coal interests, the costs are likely to be even higher. For example, during congressional action on the 1990 Clean Air Act, the last time the coal industry was challenged, union miners almost won the right to taxpayer compensation for any job losses that occurred.³⁶

The cheapest method of reducing the costs of compliance with the Kyoto protocol for the United States is to reduce our coal use very little and pay others to give up their rights to emit. Given the opposition of developing countries to participation in the allocation of quotas, the most realistic trading scheme is likely to involve only Annex I countries rather than the entire world and cost the United States about 1 percent of GDP.

Natural-gas-fired electric plant costs are now competitive with those of new coal plants, and most new electric plants in the 1990s have been natural gas fired. If that trend continues, market forces alone, in the long run, will diminish the role of carbon-intensive coal-fired electricity plants.³⁷

So large benefits are the only reason to rush the conversion from coal to natural gas. But the amount of warming prevented by full Kyoto compliance is likely to be so small (.07 degree centigrade by 2050) that it will not be easily measurable.³⁸ Even though markets are flexible and the most costly scenarios of compliance are probably over-

stated (given the track record of previous model predictions of energy prices), the almost totally symbolic benefits of the Kyoto protocol are not worth the real costs it would create.

Notes

1. Energy Information Administration, Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity, October 1998, Table C8, p. 219, <http://www.eia.doe.gov/oiaf/kyoto/pdf/sroiaf9803.pdf> (cited hereafter as EIA report); and W. David Montgomery, Statement, in U.S. House of Representatives, The Road from Kyoto--Part 4: The Kyoto Protocol's Impacts on U.S. Energy Markets and Economic Activity: Hearing before the Committee on Science (cited hereafter as Science hearing), October 9, 1998, p. 9, and Table 2, p. 13, http://www.house.gov/science/montgomery_10-09.htm.
2. EIA report, Table C8, p. 219.
3. Council of Economic Advisers, The Kyoto Protocol and the President's Policies to Address Climate Change (cited hereafter as CEA report), <http://www.whitehouse.gov/WH/New/html/kyoto.pdf>.
4. The models agree that the sum of actual cutbacks and permit purchases must total approximately 550 million metric tons (mmt) of carbon emissions in 2010. In the CEA full global trading scenario, only 12 percent, or 66 mmt, of emissions would be cut in the United States. The remaining 484 mmt of our obligation would be in the form of permits purchased from other countries. See Science hearing, Table 2, p. 13.
5. Interlaboratory Working Group on Energy-Efficient and Low-Carbon Technologies, Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy-Efficient and Low-Carbon Technologies by 2010 and Beyond (Oak Ridge National Laboratory, Lawrence Berkeley National Laboratory, Pacific Northwest National Laboratory, National Renewable Energy Laboratory, and Argonne National Laboratory, September 1997).
6. The CO₂ emissions of fossil fuels per unit energy released vary by a factor of more than two. Coal releases the most CO₂. For example, an existing coal-fired electricity plant releases 571 pounds of carbon emissions per megawatt-hour of electricity produced. An advanced combined-cycle natural-gas-fired electricity plant produces only 201 pounds of carbon emissions per megawatt-hour of electricity

(65 percent less). See EIA report, Table 17, p. 75.

7. Those 40 countries are referred to as "Annex I" countries because of the section of the agreement in which their names were signed in Rio de Janeiro in June 1992 at the first meeting of the parties to the United Nations Framework Convention on Climate Change. See CEA report, p. 93. For the full text of the Kyoto protocol, including the carbon emissions quota for each Annex I country, see <http://www.cnn.com/SPECIALS/1997/global.warming/stories/treaty/>.

8. Science hearing, pp. 10-11.

9. CEA report, pp. iv, 53-54.

10. Science hearing, p. 13.

11. See EIA report, Table ES1, p. xv.

12. Ibid., Table C8, p. 219; and Science hearing, Table 2, p. 13.

13. EIA report, Appendix C.

14. Autonomous energy efficiency is a reduction in the use of energy per dollar of economic output that occurs even in the absence of energy price increases to encourage such efficiency.

15. See Science hearing, pp. 16-18.

16. Ibid.

17. Ibid.

18. Ibid., p. 16.

19. EIA report, p. 139.

20. Ibid., p. 143.

21. Ibid., p. xiv.

22. Robert J. Barro and Xavier Sala-I-Martin, "Convergence across States and Regions," Brookings Papers on Economic Activity 1 (1991): 107-82. The authors estimate that wage differences across states and regions take approximately 70 years to converge.

23. EIA report, Table ES1, p. xv, and pp. 73-74, 93-94. In 1996 coal-fired power plants produced 92 percent of U.S. carbon emissions in the electricity sector and accounted for over a third of total U.S. carbon emissions.

24. During the 1970s, when electricity demand was growing at more than twice the rate projected in the reference scenario in the EIA model, more than 24 gigawatts of capacity were added annually.

25. EIA report, p. 78.

26. Ibid. Existing coal plants are cheap because coal is cheap, not because the plants are efficient. Coal plants use 10,000 to 10,500 British thermal units of fuel per kilowatthour of electricity produced. Gas-fired combined-cycle plants use only 6500 to 7500 Btu of fuel per kilowatt-hour of electricity produced.

27. Science hearing, p. 17. Coal shipments provided 23 percent of all rail revenue and 39 percent of revenues for major coal-hauling railroads in 1996. See EIA report, p. 143.

28. Ibid., pp. 138-39.

29. EIA report, Appendix C. The CEA model predicts about \$61 per ton for carbon emissions. Science report, p. 13.

30. See William Spangar Peirce, Economics of the Energy Industries (Westport, Conn.: Praeger, 1996), pp. 216-18.

31. Hans H. Landsberg, Energy: The Next Twenty Years (Cambridge, Mass.: Ballinger, 1979), p. 19.

32. M. A. Adelman, The Genie Out of the Bottle: World Oil since 1970 (Cambridge, Mass.: M.I.T. Press, 1995), p. 160.

33. Ibid., p. 211.

34. Energy Information Administration Annual Energy Review 1997 (Washington: Government Printing Office, July 1998), Table 5.16, p. 149; and Energy Information Administration, Monthly Energy Review, October 1998, Table 9.1, p. 111, <http://www.eia.doe.gov/pub/pdf/multi.fuel/00359810.pdf>. The average 1979 price of domestic crude oil was \$22.90 per barrel in 1992 dollars. The June 1998 price in 1992 dollars was less than \$8.90.

35. Reduced use of coal accounts for 68 to 75 percent of carbon-emission reduction in the various scenarios modeled by the Energy Information Administration. See EIA report, p. ES4.

36. The so-called Byrd amendment to provide compensation to miners failed in the Senate by only one vote. See Paul L. Joskow and Richard Schmalensee, "The Political Economy of Market-Based Environmental Policy: The U.S. Acid Rain Program," Journal of Law and Economics 41 (April 1998): 50.

37. The EIA predicts that in the absence of the Kyoto protocol almost all new facilities will be natural gas, but existing coal plants will be more intensely utilized. Thus coal's role in total electricity production rises in absolute terms but declines as a percentage of the total larger market over time. EIA report, Figure 65, p. 71.

38. See T. M. L. Wigley, "The Kyoto Protocol: CO₂, CH₄, and Climate Implications," Geophysical Research Letters 25 (July 1, 1998): 2285-88.

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