

*MIT Joint Program on the Science  
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The uses and misuses of  
technology development as a  
component of climate policy\*

*H.D. Jacoby*

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To inform processes of policy development and implementation, climate change research needs to focus on improving the prediction of those variables that are most relevant to economic, social, and environmental effects. In turn, the greenhouse gas and atmospheric aerosol assumptions underlying climate analysis need to be related to the economic, technological, and political forces that drive emissions, and to the results of international agreements and mitigation. Further, assessments of possible societal and ecosystem impacts, and analysis of mitigation strategies, need to be based on realistic evaluation of the uncertainties of climate science.

This report is one of a series intended to communicate research results and improve public understanding of climate issues, thereby contributing to informed debate about the climate issue, the uncertainties, and the economic and social implications of policy alternatives.

Henry D. Jacoby and Ronald G. Prinn,  
*Program Co-Directors*

For more information, contact the Program office:

MIT Joint Program on the Science and Policy of Global Change

**Postal Address:**

77 Massachusetts Avenue  
MITE40-271  
Cambridge, MA 02139-4307 (USA)

**Location:**

One Amherst Street, Cambridge  
Building E40, Room 271  
Massachusetts Institute of Technology

**Access:**

Tel: (617) 253-7492  
Fax: (617) 253-9845  
E-mail: [globalchange@mit.edu](mailto:globalchange@mit.edu)  
Web site: <http://web.mit.edu/globalchange/www/>

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# The Uses and Misuses of Technology Development as a Component of Climate Policy

*Henry D. Jacoby*

## INTRODUCTION

The search for low-carbon technology for the long run must be a central element in the global response to the threat of climate change. Unfortunately, actions taken by both the U.S. Congress and the Administration run the risk of crippling the U.S. effort to explore this avenue, in effect throwing out the baby with what is perceived by some to be policy bath water. In its current focus on short-term Kyoto-type emissions targets, and Congress's reaction to the process, the United States is wasting time and effort that could be applied to the search for cost-competitive, low-carbon ways of powering the modern economy. This is a tragic mistake. At the heart of the problem is a push for a short-term technical fix, driven by domestic political exigencies and unfortunately supported by badly flawed analyses of the process of technical change. The focus of this paper is one widely cited study of technology options by five U.S. national laboratories, and the uses and misuses of this work as a guide to policy.

Failure to harness technology development intelligently in response to the climate issue could have serious consequences. Although the possible magnitude of potential change is very uncertain, the risk of human influence appears substantial. Our own analysis at the Massachusetts Institute of Technology (Prinn et al. 1998) shows that the range of possible outcomes over the next century is very wide. We only partially understand climate system behavior, and our ability to forecast economic growth and technical change, and the resulting greenhouse emissions, is limited as well. Our understanding of the ecosystem effects of rapid climate change

is even weaker. The magnitude of the combined uncertainties is so great that the problem could prove either not so important as we imagine, or much worse. Thus, whatever one's position regarding the current conflict over near-term emission controls, we should, in my view, be able to agree that we are taking considerable risks with global climate in the long term.

Unfortunately, even the emergence of universal consensus that the problem is serious, and that something dramatic should be done, may not lead to meaningful action. Nations have very different interests and priorities. A treaty that could meet the needs of each, and suppress the incentive for free-riding, is difficult to formulate even as a theoretical exercise, much less to negotiate among dozens of nations. In principle, rich countries could use various forms of foreign aid, trade in emissions permits, or other side payments to gain the participation of holdouts, but the amounts of money that would be needed are very large in relation to anything seen before, or to what would seem politically feasible.

It may well be, therefore, that the key to future response capability is the development of low-carbon energy supply technologies that can compete head-to-head with conventional fossil-fuel burning, and use technologies that can deliver the same services as today with much lower energy input. We do not have these options in hand now, and their development is a long-term, multi-decade process. Moreover, at least within the next few decades we cannot look to resource depletion to have a substantial effect on the prices of conventional fossil fuels, allowing market penetration by today's relatively costly alternatives. Thus, a shift of limited R&D resources and managerial and political attention to short-term policy targets may come at the cost of long-term technical developments, to our considerable regret in the future. Unfortunately, in recent months a few prominent technology studies have lent support to just this outcome.

## **TWO APPROACHES TO ANALYZING EMISSIONS CONTROL POLICY**

To provide a context for discussion of these studies, it is helpful to have a map of the methods usually applied to studies of emissions control. As illustrated in Figure 1, they fall into two rough categories, each encompassing a rich variety of detailed methods. As the figure suggests, some analytical efforts involve a mix of the two so that the categories overlap, but the distinction nonetheless remains a useful one.

One approach, usually carried out by economists, might be called "market-based." Its concern is with how markets respond under assumed policy intervention, and the essential question is, "At what price?" That is, the focus is on market price as the essential mechanism through which policy acts. Frequently, this approach also is referred to as "top-down" analysis, meaning that it encompasses

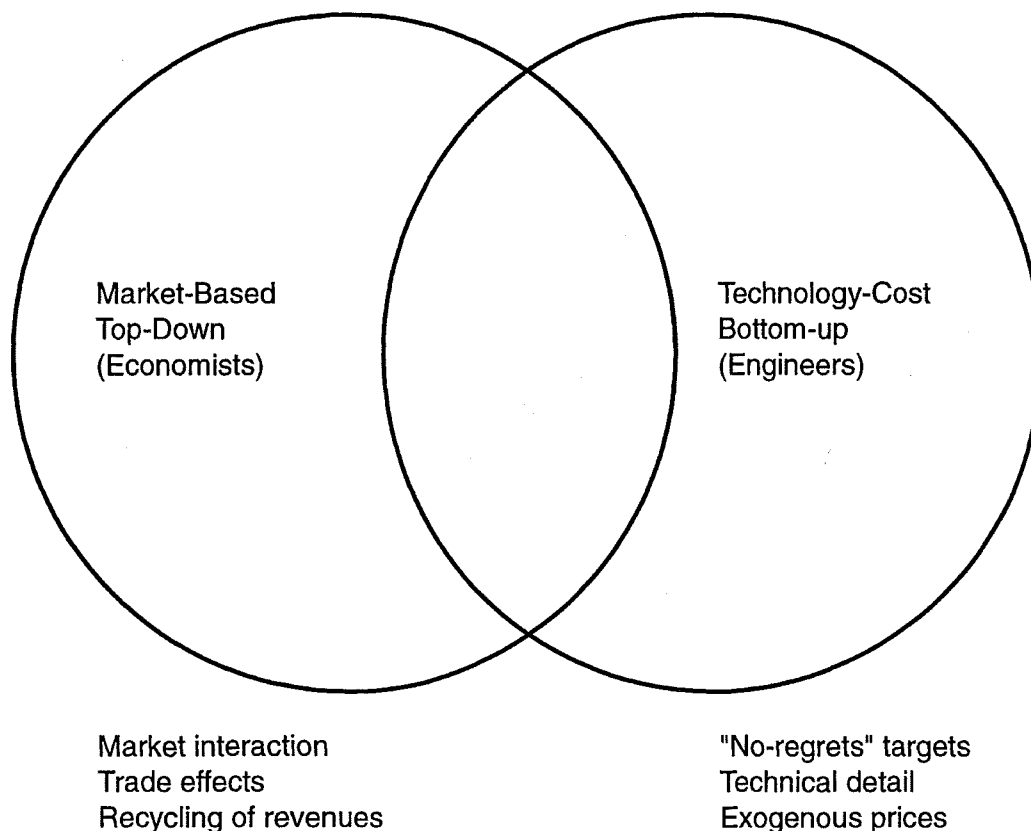
the economy as a whole (or at least a number of interacting sectors), and it analyzes the interplay of policies within this larger system. The most common alternative is "technology-cost" analysis. Often associated with studies dominated by engineers, its essential question is, "At what cost?" Its focus is on estimation of the cost of particular supply technologies and/or end-use devices, and comparison of these costs with reduced energy expenditures and other environmental benefits. It is frequently referred to as "bottom-up," in that assessment of a policy involves the adding up of energy savings or emissions reductions from various technologies, each considered independently.

Each of these two approaches to analysis has its strengths and weaknesses. Market-based methods take account of interactions in the markets for intermediate and final goods and inputs to production such as capital, labor, and natural resources, and they can take explicit account of consumer preferences and how they change with increasing wealth. They can consider the fiscal effects of policy measures such as carbon taxes or permit auctions. They also can be formulated to reflect the ways that policy impacts are mediated through international trade. In short, they can be designed to consider the side effects, spillovers, and feedbacks

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**Figure 1 Different Approaches to Control Cost**

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that flow from a policy change, the so-called “general equilibrium” adjustment of the economy.

There is a trade-off, of course. Gaining multi-sector, multi-region interactions requires a sacrifice in technical detail, through the need to use simplified representations of production processes and to aggregate industrial sectors. However, for an economic change as large as the emissions reductions under the Kyoto Protocol, these market interactions are crucial, and so these market-based methods offer significant advantages for addressing the implications of such a commitment.

The chief advantage of the technology-costing methods, naturally, is their technical detail, which makes it possible to study specific cases where markets may not be working efficiently, and to guide expenditures on technology research and development to the areas of greatest payoff. To gain this detail they usually must assume prices of energy and other key inputs rather than analyze them, and omit consideration of the many substitutions that take place among goods and processes in response to any policy action.

If done well, studies following a technology-costing approach can offer insight into larger economy-wide questions, like the implications of climate agreements. In the attempt, however, these studies frequently encounter one of several pitfalls, which can make them positively misleading as a guide to broad policy. Three of these are of particular relevance to this discussion.

### **Pitfalls of Technology-Costing**

#### *Confusion of Market Failures With Other Market Barriers.*

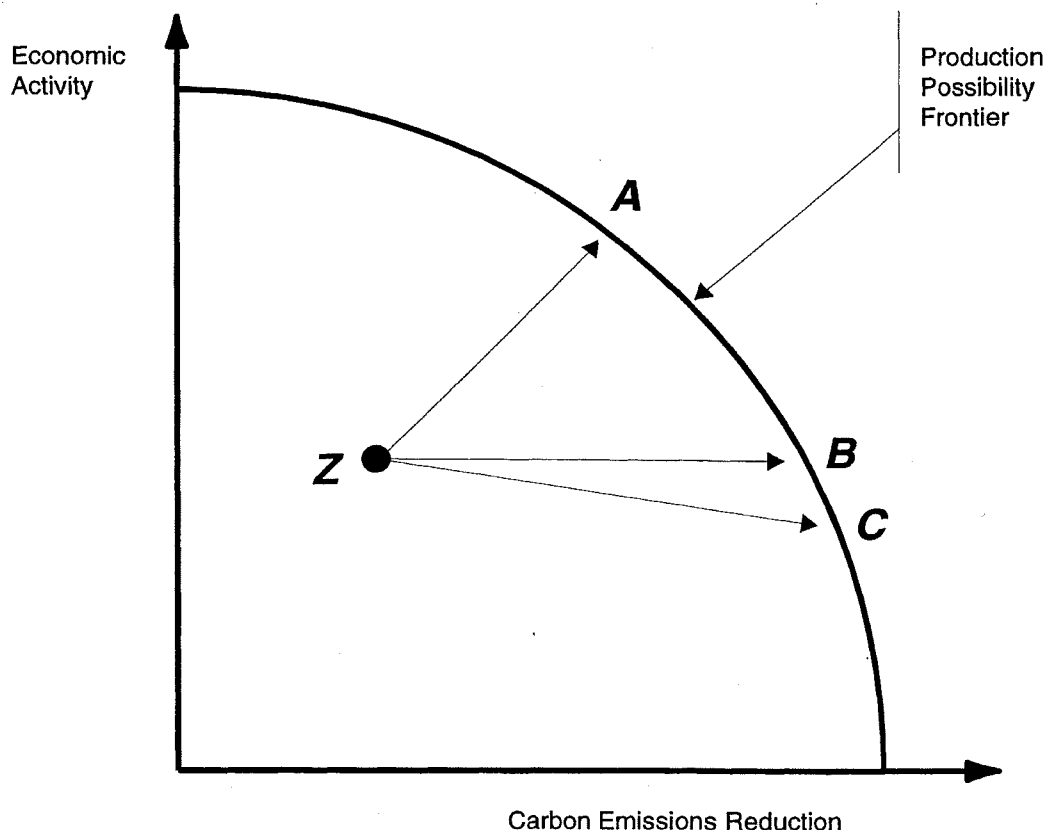
Technology-costing studies usually start with a list of particular technologies, such as energy-saving end-use devices or low-carbon energy sources, which look attractive but are “under-used.” An analytical basis for this judgment is constructed by means of a calculation of net present value (NPV), taking account of capital and other components of cost and the savings to be realized in energy expenditures. Examples of such opportunities include highly efficient windows or higher mile-per-gallon cars, and wind and solar power supplies. If such “good” technologies go wanting, then something must be wrong in the economy, so the argument goes. The analysis proceeds to show how much improvement could be gained at a low cost, or even a net benefit, with only small changes in policy or perhaps just general encouragement.

The question is, what is the barrier to use of a technology which is to be corrected by policy intervention? Here it is helpful to distinguish two possible reasons why an apparently attractive technology may not be quickly adopted. One is appropriately classified as a market “failure”; the other is not attributable to failure in market

function but to some inhibiting feature of market preferences or normal market activity (Jaffe and Stavins 1994; Sutherland 1991). The difference between the two circumstances can be illustrated using Figure 2, which is adapted from the Intergovernmental Panel on Climate Change (1996). An economy cannot produce everything its citizens want; there are always trade-offs. Here the textbook choice of “guns vs. butter” is restated in terms of some traditional measure of economic welfare vs. climate-related environmental quality. In this example, the vertical axis includes output of market-priced goods plus all environmental benefits *except* those of reducing the risk of climate change; the horizontal axis is the level of greenhouse gas emissions. The figure thus illustrates the components of a cost-effectiveness analysis of climate policy, which is the type of calculation being reviewed here. An economy is said to be “efficient” when it is not possible to lower greenhouse gas emissions without incurring welfare losses elsewhere. In the economist’s jargon, an efficient economy is on its production possibility frontier, at points like A, B, or C in the figure.

A market “failure” occurs when there is some flaw in the way markets are organized, which leads consumers and/or producers to respond to the wrong price signals. That is, the economy is operating in a state like point Z, where there may be

**Figure 2 Trade-Off of Economic Welfare vs. Emissions Reductions**



so-called “no regrets” opportunities to move to point *B*, or even *A*, thereby achieving environmental improvement at no cost or even a net benefit. Or it may be possible to move from *Z* to point *C*, which would involve economic costs but which might be justified on a benefit-cost basis. Such failures include situations where decision makers have insufficient or incorrect information (consumers do not perceive how costly it is to own a power-guzzling air conditioner), where there is an asymmetry between the person making the energy-use decisions and the one paying the bills (the landlord-tenant problem), or where there is some form of non-priced externality (such as urban air pollution). These conditions lead to calls for government action, in the interest of economic efficiency, ranging from labeling rules to device performance standards to various forms of direct government expenditure or tax subsidy.

In contrast to these market failures are another set of barriers that may retard the spread of a technology, even when analysts’ calculations show it has a positive NPV, that are better thought of as an unfortunate set of normal market preferences. In these cases, the economy is operating efficiently, and emissions reduction (perhaps through the use of a new technology) can be had only at some cost, as with a move from *A* to *B*, or *B* to *C*, in the figure. In other words, the technology is not economically competitive apart from possible expected benefits from reduced climate risk.

A wide range of normal market conditions can contribute to this result, where technology-costing analysis shows the move is costless (or a net benefit) but buyer behavior indicates otherwise. First, potential buyers simply may not like the technology. That is, it may have undesired attributes that matter to users but are not priced in the technology-cost analysis.<sup>1</sup> Or there may be transactions costs or other expenses of adoption that are hard to include in the calculations. Uncertainty about performance, or about energy prices, may lead users (quite rationally) to exercise their option to wait and reconsider the opportunity next year. And most significant is the issue of discount rates. Consumers and industry decision makers may appear to operate at discount rates higher than those that analysts choose for their NPV calculations. Sorting out the influence of discount rates from that of un-priced attributes and options behavior is a very complex matter. (Do I decide not to buy more energy-efficient fluorescent light bulbs because I over-discount the electricity savings, or because they do not look good in my existing appliances?) Still, technology-costing studies that apply discount rates below the levels generally seen in practice do not reveal a market failure so much as an analyst’s disagreement with market preferences.

The key difference between these two causes of non-use is that correcting failures may in some circumstances offer a net benefit, whereas overcoming non-failure or market-preference barriers always involves cost. The distinction is of concern in this discussion because in some technology studies these two effects are mixed indiscriminately. Too often market intervention to advance a particular



technology is implicitly assumed to be correcting failures, and therefore the analysts feel no need to dig into specific policy instruments and their costs. An example of this phenomenon will be seen later.

#### *Lack of Attention to Market Structure*

In analyzing a new technology, such as a consumer device or production process, it may be difficult to account for all the conditions (besides engineering NPV) that must be met before it can take market share. It can be even harder to estimate how long the process may take. Aspects of market structure, which are outside the usual boundaries of technology-cost analysis, are crucial at this point. These factors include the structure of distribution channels and industries supplying key (and perhaps new) inputs, and they may involve regulatory and legal liability issues particularly regarding health, safety, and environmental quality. Most important, they include the internal organization of the particular industry—firms, consumers, and intervening markets—that is to adopt the technology.

These aspects of detailed market structure may or may not determine the fate of a new technology in the long run, but they have a huge influence on the likely pace of adoption. Failure to consider them may lead (incorrectly) to a judgment that something is “wrong” with the market, or if truly wrong that it is fixable at reasonable cost. Such faulty analysis can lead to bad policy advice.

#### *Failure to Account for Inter-Market Adjustments*

Finally, in a partial analysis built up from assessments of individual technologies, and policies to foster them, it is very difficult to consider interactions across markets. If the changes are small, then this aspect can be ignored. If these effects are large in relation to the markets at issue, however, then failure to consider them can lead to serious flaws in the analysis. Proposed climate policies, which involve major shifts in the structure of energy supply and use, present such a case. An obvious source of concern is the evaluation of a large-scale policy-induced change in use of a particular fuel or other input, when the study assumes an exogenous (and constant) estimate of its domestic price. Some changes in technology may also influence the prices of capital and specialized labor. Less obvious, but nonetheless significant in some cases, are interactions through international trade.

### **THE DEPARTMENT OF ENERGY’S FIVE-LABS STUDY**

An example of how a study can suffer from the ills above, and yet be applied to an important policy issue, is the analysis of U.S. carbon reductions prepared by

a consortium of five U.S. Department of Energy laboratories, frequently referred to as the Five-Labs report (Interlaboratory Working Group 1997). Beginning with an observation that many energy-efficient technologies remain “underutilized,” it sets out to “...quantify the reductions in carbon emissions that can be attained through the improved performance and increased penetration of efficient and low-carbon technologies by the year 2010” (p. 1.1). It has proved an influential piece of work, as discussed below. Its dominant and much-publicized conclusion is that, by pursuing a technology path, the United States could stabilize carbon emissions at 1990 levels, at no cost or even a positive net benefit. As stated in the report, if certain measures discussed are taken, “...the cases analyzed in the study are judged to yield energy savings that are roughly equal to or greater than the costs” (p. 1.1).

### The Study’s Structure

The Five-Labs study divides the U.S. energy economy into four sectors (buildings, industry, transportation, and electric utilities) and compiles estimates of how carbon emissions in 2010 could be reduced by means of a technology push. Reductions in energy and carbon emissions are calculated from a baseline or “Business as Usual” case drawn from forecasts in the Energy Information Administration’s 1997 *Annual Energy Outlook*. Possible carbon reductions are described for three policy cases:

- **Efficiency case.** This case presumes “...an invigorated public- and private-sector effort to promote energy efficiency through enhanced R&D and market transformation activities.”
- **High-Efficiency/Low-Carbon (HE/LC) Case with a \$25 price per ton of carbon (\$/tC).** This case presumes that the carbon premium is attained through a cap-and-trade system. This policy is accompanied by a “greater commitment” through federal programs, strengthened state programs, and “very active” private-sector involvement.
- **High-Efficiency/Low-Carbon (HE/LC) Case with a \$50/tC price.** This case doubles the carbon price but is otherwise the same.

Given the “Business as Usual” Department of Energy forecast of emissions which the study uses, a return to 1990 levels would require a reduction in 2010 emissions of 390 million metric tons of carbon annually.<sup>2</sup>

The sector breakdown of these reductions is shown in Table 1, which is drawn from Table 1.2 of the Five-Labs report. Before looking at some of the assumptions behind these estimates, two general points should be made about the analytical method. First, only in the case of the electric sector has the Five-Labs group conducted any numerical analysis of the potential effects of carbon prices. For all other sectors, the net decreases in carbon emissions are the result of “expert” judgments about the effects of price and the assumed effect of a “greater commitment” by government and the “very active” private sector that might accompany the imposition of a permit scheme.

Second, the study does not describe the policies that might be used to accomplish higher penetration of energy-efficient and/or low-carbon technologies. There is not even any explicit treatment of the reasons why emissions should be lower in the Efficiency case than under Business as Usual. The report simply posits a “host of market barriers [that] account for the lost opportunities,” with no attempt to sort out the failures-vs.-preferences puzzle discussed above.

### The Study’s Shortcomings

Based on these observations, and others below, many criticisms can be leveled at the Five-Labs study (for example, see Sutherland 1998, U.S. General Accounting Office 1998). It also should be noted that the authors were aware of many of its shortcomings and cite them in the body of the study and its appendices. The argument here is not that the staffs of these national laboratories did not know what they were doing, or that they hid the blemishes from the diligent reader. The central critique is that the Five-Labs study is not an appropriate vehicle for analysis of the policy question which its main conclusion addresses, i.e., how costly it would be to return to 1990 U.S. carbon emissions by 2010. A look at the details of just three of the many components of the analysis—for automobile fuel economy,

**Table 1 Forecast for Carbon Reduction Below the 2010 Baseline**  
Millions of metric tons of carbon

	Efficiency	High Efficiency/Low Carbon	
		\$25/tC	\$50/tC
Buildings	25	44	62
Industry	28	54	93
Transportation	73	88	103
Electricity	0	48	136
Total (rounded)	120	230	390

building efficiency, and reduction of coal use in electric power—will illustrate the cause for concern.

*Automotive Fuel Efficiency: Regulation Is Costless*

As can be seen in Table 1, over half of the carbon reduction in the Efficiency case is realized in the transport sector. Of the 73 million metric ton reduction, 61 million metric tons or 84 percent is from increases in vehicle efficiency and the remainder results from the assumed introduction of ethanol from biomass. Here we focus on just the main component of this estimate. The increase in efficiency is the result of the assumed market penetration of new technologies such as direct-injection stratified charge engines, direct-injection diesels, and gasoline- and/or diesel-electric hybrids, in addition to other changes in vehicle design and materials. In the overall cost analysis, the additional capital cost of these vehicles is weighed against the assumed fuel savings, with market penetration rates and other calculations performed using the Energy Information Administration's National Energy Modeling System (NEMS) model.

The question is, why should these efficiencies appear in the Efficiency case but not in the baseline, when there are no price incentives such as higher gasoline prices? The answer comes in two parts. First, vastly increased R&D is assumed to reduce the time required for market introduction of new technologies by 25 percent (by a mechanism that is not explained). But second and most important is the following:

*[The study] assumes that policies necessary to draw energy-efficiency technology into the market are implemented as needed...[including] fuel economy standards, revenue neutral feebates, fuel taxes, public information, or some other initiative (p. 5.3).*

That is, underlying the analysis, which is supposedly about technology, is a regulatory and tax program. The components of such a policy program receive no analysis in the study, and only the barest description beyond what is quoted here. As noted earlier, the study is explicit about its lack of analysis of specific policies, but less obvious is the fact that any costs of such a regulatory and tax program are omitted from the benefit-cost analysis. In effect, regulation and tax programs are treated as politically acceptable and free of economic cost. Thus, the analysis is best described as a scenario exercise gone haywire, not a plausible economic forecast as implied by the study's conclusions and the way they have been interpreted in policy discussions.

When the report comes to the HE/LC cases, the analysis descends even deeper into the imaginary world of "what if." As noted earlier, there is no analysis of the

potential effect of the \$25 or \$50 per ton carbon price (\$50 per ton of carbon would add roughly \$0.125 per gallon to the gasoline price). Instead, the additional reductions derived for these cases, shown in Table 1, are based on “technological breakthroughs” and “a certain degree of luck” (p. 5.3). Lost in references to this study in policy discussions is the fact that the report itself declares that the HE/LC case is best described as “optimistic” or “possible,” and that in addition to a major intensification of R&D it presumes the adoption of “...significant policy measures aimed at pushing the market towards giving fuel efficiency a much higher priority” (p. 5.3). In the terms introduced above, the study implicitly assumes that regulatory or tax intervention is justified by the correction of (unspecified) market failures, so the costs are not important to the analysis. As a result, the economic cost analysis is not correct, the considerable political difficulties of “pushing the market” are hidden, and thus the future the report lays out is not realistic. Moreover, little evidence is presented that this market push could produce the promised magnitude of energy and carbon savings, even if it were somehow carried out.

*Building Efficiency: Arbitrary Assumptions About Markets*

The study’s handling of the building sector provides a disturbing example of the failure to consider the structure of markets when preparing this form of technology-cost analysis. To arrive at the carbon reductions presented in Table 1, the study first constructed an estimate of how much energy and carbon would be saved if maximum cost-effective energy improvements were installed in 100 percent of U.S. homes and commercial and public buildings. These improvements include appliances such as lighting, refrigeration, and space-conditioning equipment, and more effective building design and construction. The definition of “cost effective” for this analysis is a positive NPV to the user, assuming a 7 percent real discount rate.

For the Efficiency case, it is assumed that 35 percent of this maximum reduction is achieved. Why the Efficiency case should differ from the baseline in this way (with no price incentives) is not discussed, except to say that the expected savings result from a “moderately vigorous” effort to reduce energy use by “[a] combination of mechanisms that may include higher prices...energy-efficiency standards and information programs” (p. 3.11). The HE/LC cases assume that 65 percent of the maximum is achieved. Again, prices of energy, as they might be influenced by the carbon permit system, are not considered explicitly. Rather, the 65 percent result flows from a judgment as to the effect of a “vigorous effort” to reduce energy use (in contrast to a “moderately vigorous” effort in the Efficiency case). That is the extent of the reported analysis.

The study imagines an appliance and construction market with a structure quite different than the one we actually have. With a straight face, the Five-Labs

authors justify the 7 percent discount rate on the basis that, "The long term average return for the utility industry is about 6 percent real and the typical rates for auto loans and business loans are also in this range" (Appendix C, p. 1.5). Controversy over the economics of demand-side management programs conducted by U.S. electric utilities spawned a large amount of careful work on consumer and industry behavior in the area of energy-efficiency investments (e.g., Joskow and Marron 1992; Levine and Sonnenblick 1994; Nichols 1994). In the light of this work it is clear that 7 percent is far below actual experience, and any analysis using such a low rate is seriously misleading.

Also included in the savings in building efficiency is the effect of "vigor" and "moderate vigor" on the design, construction, and equipping of new residential and commercial structures. Here again, forecasting the response of this industry to heightened societal concern for conservation, and perhaps to price incentives flowing from the carbon permit scheme, requires consideration of its peculiar structure. The U.S. construction industry is notorious for the fragmentation of its various components such as local building codes, development and finance, design, construction (with its various layers of subcontractors), materials manufacture and supply, certification, and training of construction trades. To be realistic, any analysis of response to policy must reflect the inertia of this system (Hansen 1998). It is an issue that the study does not address.

Thus, the 35 percent or 65 percent numbers, which reflect progress toward some maximum potential, involve seriously flawed assumptions about the structure of markets in this sector, and unspecified policy intervention. As such, it may be a start toward an analysis of long-term potential and sector-specific policies, but it is not a reasonable approach to estimation of likely developments by 2010.

#### *Electricity: Ignore Inter-Market Adjustments*

The electric sector is the one place in the Five-Labs Study where explicit account is taken of the potential effect of a cap-and-trade system. As Table 1 shows, 136 million metric tons of carbon or one-third of the reduction needed to achieve the 390 million metric ton reduction in 2010 comes from the electric sector. Here, we focus on the shift from coal to natural gas in existing generators, which accounts for 70 percent of the total. The remainder of the savings come from a combination of small contributions from biomass, wind, hydro, and nuclear sources, and various improvements in other parts of the electric system.

The results in Table 1 are calculated on the basis of only one case of an emissions permit system, i.e., the one yielding a carbon price of \$50 per ton of carbon. (The \$25 case was constructed using analysts' judgment.) System calculations were made using a simulation model of the generation sector. A base case was constructed to

approximate the results under the Energy Information Administration's 1997 *Annual Energy Outlook*, which underlies the analysis of other sectors, and an attempt was made to adjust the model for market changes that will accompany the current process of electricity deregulation. Then analysis of the \$50 per ton carbon case was conducted in two parts: adjustments on the demand side, and changes in the supply structure. First, as a result of lowered end-use of electricity in the Building and Industry sectors, the demand for electric generation will be reduced. Some of this effect is already accounted for in these other sectors, but not counted there is the fact that, with lower overall electricity demand and the new carbon emissions charge, there will be a re-dispatching of existing generating units, in general away from coal. Second, whatever the demand level, coal-fired units will be re-powered with lower-carbon-emitting natural gas.

Unfortunately, at this point the study drops into the third of the pitfalls laid out above. Underlying all of the model results is the key assumption that the prices of oil, natural gas, and coal are constant. This condition holds across all cases (Appendix F-2). This of course means that the coal-gas price ratio, which is a crucial input to the calculation of coal to gas conversion, also is constant. In reality, if coal demand falls domestically because of climate policy (electric generation accounts for about 80 percent of U.S. coal use), coal prices will fall as well. Since the United States is a net exporter of coal, and any U.S. domestic carbon control policy presumably will have counterparts in other countries, this price response will be augmented through international trade. Also, the conversion of coal plants to natural gas will cause a substantial increase in gas demand, driving up its price. In omitting these intermarket effects, the Five-Labs analysis overestimates the carbon reductions from re-dispatch and re-powering. In addition, the calculated fuel shift is strongly influenced by assumed prices of emissions permits under sulfur and nitrogen oxides control programs, but these prices also are held constant even with drastic reductions in coal use.

Without reanalysis, taking account of the changing market equilibria in these closely related markets, it is not possible to say how big an error is introduced by this procedure. Note, moreover, that this assumption of constant prices will bias the estimates of the penetration of other contributors to carbon reduction in the electric sector such as biomass, wind, and solar power.

In short, it is not correct to calculate these changes in generation patterns in a partial or one-sector analysis, ignoring the response of fuel prices. To be fair to the Five-Labs effort, it should be said that the authors do describe their method in one place or another, and they are explicit about the fact that they did no analysis of natural gas or coal prices (p. 7.3 and Appendix F-1). It is not that work underlying the sector chapters and appendices is misrepresented, or that an effort was not made to lay out a set of interesting scenarios. The problem is that this technology-costing

analysis, with its particular structure, is simply inappropriate for the policy question at which it is directed.

## APPLICATION TO ADMINISTRATION POLICY, AND ITS CONSEQUENCES

It would be easy to overstate the influence on government policy of any particular piece of analysis. Diverse forces come to bear, many of them much more powerful than the computer model and the word processor. However, recent U.S. climate policy, particularly as it concerns the role of new technology, is a case where this influence merits greater attention. By the same token, it is not altogether fair to single out the Five-Labs report for criticism, because it is only one of a number of studies that offer a similar brand of technological optimism (e.g., National Academy of Sciences 1991; Alliance to Save Energy et al. 1997). On the other hand, the Five-Labs study has proved to be an influential piece of work, frequently cited as justification for a technology-based approach to climate change in the short term. Of course, the policy consequences should not be attributed to the Five-Labs study alone, but equally to those who misapply its results (and those of other studies like it) in climate discussions.

### U.S. Climate Policy and Its Analytical Justification

The outlines of U.S. climate policy were stated by President Clinton in an October, 1997, speech at the National Geographic Society (White House 1997a). The President instructed U.S. negotiators to seek agreement to a legally binding target of returning to 1990 emissions by a 2008–2012 budget period, a target tightened to *minus* 7 percent in the subsequent Kyoto Conference of Parties (United Nations 1997). Further, the President's speech laid out a three-stage approach to attaining this goal. The first and key stage was a technology initiative. The plan involved \$5 billion in additional federal expenditures over five years for tax incentives, R&D spending, and various federal energy initiatives, plus a program of jawboning of U.S. industry. No additional actions were foreseen for seven years or more! Only after "...a decade of experience, a decade of data, a decade of technical innovation" did the plan foresee a need to impose significant economy-wide economic incentives. These are to be in the form of a system of tradable emissions permits, "to insure that we hit the binding targets."

Most forecasts show U.S. carbon emissions, without policy, to be one-quarter to one-third above 1990 levels by 2010, yet at the time of the anticipated "launch" of this permit system the start of the first budget period would be less than three years away. At one point in the press briefing that followed the President's announce-



ment, the chair of the National Economic Council, Gene Sperling, declared, “The plan that we have as you look forward does not include increased energy prices” (White House 1997b). Thus, the plan had to assume great success from the technology initiative. As one wag put it, “It was the tooth fairy in reverse: put \$1 billion per year under your pillow, and in the year 2010 you’ll find teeth capable of eating 400 million tons of carbon!”

How could this proposal pass the laugh test? One justification was the Five-Labs study, with its forecast that emissions stabilization could be achieved at a net gain to the economy (Interlaboratory Working Group 1997; Romm et al. 1998). Indeed, when questioned in the briefing about the analytical basis for the plan, Sperling replied,

*But we have certainly been locked in doing a tremendous amount of economic analysis...for example there is the Five-Labs study...from the Energy Department, there is very careful analysis on what the potential is for reducing metric tons of carbon through the efficiencies in three main sectors—the building, the transportation, and the industrial sectors (White House 1997b).*

As the year wore on, the Five-Labs analysis continued to be used as a validation of the proposed policy. In Senate committee hearings in the wake of the Kyoto meeting, the chief U.S. negotiator, Undersecretary of State Stuart Eizenstat, was questioned about the analytical basis for the positions the United States had accepted. In part, his response was

*We also have...something called a Five-Labs study that was done by the five national labs. They’re totally independent—you know, nobody told them what to come up with—and they made some findings about what technology can do and how we can reduce the burdens and costs on coal miners and others by coming up with what is the hallmark of America, and that is ingenuity and technology (U.S. Senate 1998).*

As recently as June 1998, a top Department of Energy official testified that R&D was a key element of our response to climate change, and that

*Last year, a peer-reviewed study conducted by five national laboratories recognized that the United States can hold down the costs of meeting climate change goals...In fact, the study concluded that significant progress in reducing greenhouse emissions could be achieved without increasing the nation’s total energy bill (U.S. House of Representatives 1998b).*

Later, in an effort led by the President’s Council of Economic Advisors, the Administration presented a full analysis of its Kyoto position, this time based on top-

down models (Executive Office of the President 1998). The study included unreasonably optimistic assumptions about the extent of an international permit trading system to be in place in time for the first budget period, but at least the paper is clear about the policy measures to be used and their economic basis. Interestingly, the Five-Labs study merited only a passing reference in this later Administration analysis. This type of technology-costing study nonetheless continues to be influential in public discourse, because it makes a point that many players want to hear: that is, that even large-scale, short-term carbon reductions will be cheap.

### The Consequences

An important consequence of this approach to technology development is the subversion of what is essentially a long-term policy tool to the service of short-term emissions goals. In February, 1998, when the 1999 budget was put forward, the Administration's October proposal emerged as a five-year \$6.3 billion Climate Change Technology Initiative (CCTI). The major portion of this funding was proposed not for R&D but for tax expenditures and other measures intended to spur adoption of *existing* technologies. That is, "...to stimulate adoption of more efficient technologies in buildings, industrial processes, vehicles, and power generation" (OMB 1998). The plan is heavily biased toward resolving problems of market barriers, as described above, based on justifications that sound a lot like the assumptions in the Five-Labs Report.

By coincidence, it was also in the fall of 1997 that a study by a panel of the President's Committee of Advisors on Science and Technology (PCAST) presented its carefully reasoned recommendations for a program of long-term R&D focused on climate issues (PCAST 1997). However, although the CCTI contains useful expansions of some existing federal R&D programs, the PCAST report and other studies of the long-term climate issue appear to have had little effect on the overall allocation of the proposed new resources. To the contrary, the desire to produce results by a technology path within the 2008–2012 budget period appears to have been the stronger influence on the design of the CCTI.<sup>3</sup>

Even worse, this focus on short-term emissions goals threatened the loss of or drastic reduction in the CCTI program itself, including the portion that *does* contribute to long-term R&D. This is because of a backlash in the Congress over "implementation without ratification." Some members express a fear that the Administration is trying to achieve the goals of the Kyoto Protocol even though it has not been ratified (or even submitted for ratification), ignoring the stringent conditions for approval set by the Senate (U.S. Senate 1997).

This larger issue of ratification and implementation are beyond the scope of this paper. The one aspect that is of concern here, however, is the fact that long-term

R&D, which might receive widespread congressional support as prudent preparation for an uncertain and risky future, has become caught in the fray. Happily, a cut-down version of the first year's funding for Administration's CCTI proposal survived the 1999 omnibus spending compromise, reached in fall 1998. But this achievement came in the face of opposition by key members of Congress on the grounds that "...[the] \$6.3 billion initiative is intended to help meet emissions reductions mandated in the Kyoto Protocol" (U.S. House of Representatives 1998a). It is lamentable that key preparations for the long road are so deeply tangled in a debate about the first steps.

## CONCLUSION

Technology-costing studies, like the Five-Labs report and its cousins, can be a useful input to climate policymaking. They point to possible market failures; they help sort out the most important targets for R&D and perhaps for selected technology-push investments; and they help provide justification for these activities. However, it is very important to avoid misuse of these studies. There is no technical fix in the short run of a decade or so, readily available at little or no cost, as implied by the Five-Labs report. Science does not run on the policymakers' clock; new technologies frequently require breakthroughs and they take time to develop; markets for new consumer devices and industrial processes, including needed distribution and materials supply systems, require time to evolve. Further, capital turnover has its own internal dynamics, particularly in the heavily capital-intensive subsectors of energy supply. In the long run of several decades, and with a well-designed effort, the prospects are brighter. Indeed they must be brighter if we are to have any hope of an effective response, should the climate picture darken. For example, the Kyoto commitments are just an easy first step compared to the carbon reductions needed to achieve ultimate stabilization of atmospheric concentrations (Jacoby, Schmalensee, and Reiner 1997).

However, enthusiasm for the task does not mean that it will be easy to do well, or even that we know very clearly how to proceed. At the level of basic science, with its public good characteristics, the role of government expenditure is clear. At subsequent stages of technology development and application—such as pilot facilities, commercial demonstration plants, and subsidy schemes to seek benefits of economies of scale and learning—the history is mixed. Picking winners is a difficult art, and spending money effectively is a daunting challenge in the midst of regional and industrial demands for a share of the pie. Most important, the expertise in many technical areas resides in private industries—particularly oil, chemicals, and electric power. Government-industry partnerships and tax subsidies can help direct their efforts, and useful experiments are now being tried. But the only way to

truly attract industry attention is through an influence on the bottom line, which necessarily involves (among other things) price expectations. In the energy sector, at least, large-scale technical change with no price incentive is a non sequitur.

Precisely because it is such a complex task to devise policies that can hasten major technical advances in energy supply and use, it is important to free decisions about these important long-term measures from disputes over short-term policy issues. Our long-term outlook can be hopeful, provided a well-designed effort is launched and sustained. A key step in this process is to put studies of technology cost in their proper place, and avoid their misuse as guides to short-term policy development.

## NOTES

1. A classic example is the finding that a highly cost-effective energy-saving technology would be to cover the roofs of all U.S. residences with white paint (National Academy of Sciences 1991). The analysis does not ask the question whether people want to do this and how they might be encouraged to carry it out, or what they might pay to avoid it.
2. The size of the needed reduction is subject to considerable uncertainty (Webster 1997). Our MIT reference forecast implies a 470 million metric ton reduction would be needed to achieve 1990 levels, and the latest Administration analyses use 2010 baselines which would yield a number in the same range (Executive Office of the President 1998, U.S. Department of Energy 1998). The larger the number, the higher the cost.
3. As argued by Jacoby, Prinn, and Schmalensee (1998), long-term R&D was only one of several long-term tasks that have taken a back seat to the push for short-term targets for the richer countries.

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Massachusetts Institute of Technology  
Joint Program on the Science and Policy of Global Change  
One Amherst Street (E40-271)  
Cambridge, Massachusetts 02139-4307