The Economics of Strategies to Reduce Greenhouse Gas Emissions

Lisa J. Cameron,
W. David Montgomery,
Harry L. Foster

Numerous engineering studies claim that certain energy-efficient technologies pay for themselves, while at the same time reducing carbon emissions that contribute to climate change. These studies often proceed to argue that government policy should be used to promote such technologies, because they would be sound investments even if it were discovered that climate change itself did not produce significant damages. Our study establishes a framework for evaluating these claims. We review several prominent engineering-based studies in light of our framework and show that the role for beneficial policy intervention is much more limited than engineering-based studies would suggest.

Selon de nombreuses études d'ingénierie, il existe des technologies en économie d'énergie qui ont pour résultat l'amortissement aussi bien que la réduction des émissions de carbone, facteurs de contribution au changement climatique. Ces études vont jusqu'à exposer les raisons en faveur de politiques gouvernementales pour la promotion de ces technologies: elles seraient un bon investissement même si on découvrait que le changement de climat, en lui-même, ne provoque aucun dommage important. Notre étude établit un cadre d'évaluation pour examiner ces suggestions. Nous révisons plusieurs études importantes et nous montrons que le rôle d'une intervention politique est beaucoup plus restreint que ne le suggère ces études.

Dr. Lisa Cameron is a Senior Consultant at Lexecon, an economic consulting firm with offices in Cambridge, Massachusetts and Chicago, Illinois. Dr. W. David Montgomery and Dr. Harry L.Foster are both affiliated with the economic consulting firm, Charles River Associates (CRA). Dr. Montgomery is a Vice President in CRA's Washington D.C. Office and Dr. Foster is a Senior Associate in CRA's Boston, Massachusetts office.

I. Introduction

The proposition that significant reductions in energy consumption can be achieved at no cost or with positive economic benefits has played a central role in the climate change debate. One of the many prominent examples of this view is a recent study prepared by the Intergovernmental Panel on Climate Change (IPCC), which states that "Despite significant differences in views, there is agreement that energy efficiency gains of perhaps 10 to 30 percent above baseline trends over the next two to three decades can be realized at negative to zero net cost."[1] Echoing this view, President Clinton recently asserted that "conversion of fuel to energy use ... is extremely inefficient and could be made much cleaner with existing technologies or those already on the horizon in ways that will not weaken the economy but will in fact add strength in new businesses and new jobs."[2]

[1] Intergovernmental Panel on Climate Change (1996) *Climate Change 1995: Economic and Social Dimensions of Climate Change* (Cambridge, England: Cambridge University Press).

[2] Remarks by the President on Global Climate Change (1997) (Washington, DC: National Geographic Society), p.2.

Currently, the main source of support for these views comes from engineering studies. These studies begin with a description of currently available energy-efficient technologies for certain end-uses such as heating, cooling, refrigeration and lighting. Next, they estimate energy savings that could be achieved by adopting these technologies for certain applications. Typically, results show that for numerous energy-efficient technologies, the benefits of reduced energy expenditures in the future far outweigh capital and other upfront costs. Some participants in the energy policy debate interpret these findings as evidence of consumer irrationality and argue that government policies are required to promote energy-efficient technologies. Policies to promote these technologies are sometimes referred to as "no regrets" strategies, based on the argument that they will produce net benefits even if it is discovered that climate change itself does not result in significant damages.

In contrast, most economists assume that consumers are rational and offer two alternative explanations for consumers' failure to adopt energy saving technologies: market barriers and market failures. Market barriers, which are hidden costs, difficulties or disadvantages perceived by users, are present in all markets. Because entrepreneurs have a profit incentive to reduce or eliminate these transactions costs, policy intervention to eliminate market barriers is not needed and may, in fact, be counterproductive. In contrast to market barriers, market failures are conditions in markets that prevent the correct price signals from reaching decision-makers. When policy interventions are targeted at specific instances of market failure, they can increase efficiency, if the benefits of using policy to ameliorate the market failure outweigh the policy's implementation cost.

The purpose of this paper is twofold. First, we provide a framework for critically evaluating studies that claim the existence of significant opportunities to reduce emissions at zero or negative net cost. Second, we attempt to identify those cases in which policy intervention may improve the functioning of energy efficiency markets. Section II discusses the various market failure and market barrier explanations for consumers' failure to adopt energy efficiency equipment. Section III reviews prominent examples of technology-based studies in light of this framework. Section IV presents conclusions about the relevance of the existing technology-based literature to the policy debate on the use of "no regrets" strategies to reduce carbon dioxide emissions.

II. Review of Market Failures and Market Barriers

This section lists and describes all of the market failures and market barriers that have been advanced as potential explanations for slow diffusion of energy-efficient technologies.[3] Of course, the market barriers and market failures that we discuss below are not mutually exclusive. A careful assessment of the market potential of potential energy-efficient technologies may need to address several or all of these factors.

A. Market Failures

Three of the most important examples of energy market failure that have been identified are underprovision of information with public goods attributes, asymmetric information in landlord tenant relationships and the divergence of energy prices from marginal cost.[4] Below, we discuss

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[3] Generally speaking, we believe that it is important to focus on specific end-uses and technologies in testing for the existence of market failures and barriers. Because energy efficiency technologies are heterogeneous, the existence (or non-existence) of more general market failures typically cannot be inferred from the operation of the market for a single technology

[4] In addition, some recent studies have argued that declining energy R&D expenditures may cause promising technology options to be foregone (see for example, Interlaboratory Working Group on Energy-Efficient and Low-Carbon Technologies (1997) *Scenarios of U.S. Carbon Reductions—Potential Impacts of Energy Technologies by 2010 and Beyond.*) Although it might be argued that government funding is needed to promote basic research, most advocates of

these sources of market failure in greater detail and note the standard policy remedies for each source of market failure.[5]

1. Underprovision of Information with Public Goods Attributes

Public goods tend to be underprovided by the market because it is difficult to compensate sellers for their production and use. As pointed out by Jaffe and Stavins (1994a), information about whether a profitable energy-efficient innovation exists and how it should be used probably has public good attributes. In contrast, information about how the innovation fits into a consumer's home and the prices and reliability of equipment vendors is generally a private good.

Traditionally, public good problems alleged to exist in energy efficiency markets have been addressed with "command and control" regulations such as building codes and mandatory appliance standards, which simply mandate a particular level of energy efficiency. However, a more appealing remedy for these problems is to provide consumers with additional pertinent information. This policy addresses the source of the market failure directly, while preserving consumer choice.

2. Asymmetric Information in Landlord-Tenant Relationships

Asymmetric information arises in landlord-tenant relationships because landlords and tenants often cannot accurately monitor each other's behavior. As a result, the decisions these parties make about energy efficiency can be non-optimal. For example, landlords who pay their tenants' energy bills often find that their tenants are less motivated to keep the thermostat high in summer and low in winter. Fortunately, this so-called moral hazard problem can often be mitigated by appropriate contractual arrangements.

A second type of asymmetric information problem, adverse selection, arises when landlords cannot credibly establish the energy efficiency of the heating and cooling equipment that they have installed. Adverse selection reduces landlords' incentives to make such investments because customers will not pay higher rents based on energy efficiency claims that cannot be verified easily. This problem can be addressed with public policies that require landlords to accurately disclose their energy efficiency investments to potential tenants.

3. Electricity Prices that Diverge from Marginal Cost

The price of electricity can vary from marginal cost for a number of reasons. Most importantly, electricity is typically priced on an average cost basis that conceals from customers the incremental costs of new energy supplies.[6]

At first glance, this market failure in electricity pricing appear to offer a plausible explanation for the slow adoption of energy efficiency equipment. However, there may be as much electricity that is sold at a price exceeding marginal cost as there is electricity that is sold at a price below marginal cost. Although market failures result when electricity prices are either above or below the marginal social cost of producing electricity, only electricity prices below marginal cost can slow the diffusion of energy-efficient equipment.

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policies to promote the adoption of energy-efficient technologies point to cost-effective technologies that currently exist or are already on the horizon.

[5] The first two market failures have been advanced to explain the "efficiency gap," which is the difference between consumers' actual equipment choices and the choices they should make if engineering calculations are correct about savings associated with new technologies.

[6] It might also be argued that environmental externalities conceal from consumers the true social cost of energy supplies. However, existing environmental regulation of power plants, including fuel taxes, may already internalize a large chunk of the pollution costs of power generation, as argued by Black and Pierce, 1993.

If electricity prices differ greatly from marginal costs because regulated electricity rates are based on average cost, then the emergence of competition in generation should ease this problem over time. In the interim period before competition is fully implemented, policymakers may wish to consider the costs and benefits of redesigning rates to reflect marginal costs. Finally, government subsidies for electricity use, like those provided by the Bonneville Power Administration, should clearly be eliminated

B. Market Barriers

There are at least four market barriers that can induce rational consumers to reject apparently promising energy-efficient technologies even when no market failures are present. First, consumers may reject new energy-efficiency equipment because its qualitative attributes are less desirable than those of the technology currently employed. Second, consumers may reject new equipment because their usage patterns differ from those of the average consumer, a factor often ignored in engineering analyses of the technology's potential. Third, consumers may be reluctant to spend the time and money needed to ascertain whether an energy efficient innovation works well in their own homes. Fourth, it may be rational for consumers to apply a high discount rate to future energy savings when they face borrowing constraints or uncertainty about the future costs of energy-efficient technologies and associated energy prices These four market barriers are described in detail below.

1. Differences in Technologies' Qualitative Attributes

One reason that engineering studies may find that consumers are rejecting seemingly cost-effective energy efficient investments is that these studies ignore undesirable attributes of the energy-efficient technology. For example, many technology-based studies of vehicle fuel efficiency essentially ignore the value that consumers place on higher performance and other attributes that may be negatively correlated with fuel economy. Another important product attribute that is often overlooked is reliability. For equipment delivering highly valued services, even relatively large savings in energy consumption can easily be offset by a small increase in the probability that the equipment will experience breakdowns. This factor may be especially important for technologies that are relatively new to the market. Of course, it is equally important to ensure that improvements in attributes associated with the introduction of alternative products are captured as benefits of the new technology.

2. Heterogeneity in Consumer Usage Patterns

Another measurement error that can lead engineering studies to overestimate the potential for energy-efficient technologies is the assumption that all consumers will reap the same energy savings as the average consumer. This error produces upward bias in the measure of a conservation investment's penetration potential. If the relevant population is heterogeneous with respect to energy use, even a technology that is cost effective for the average user will not be attractive for a large proportion of the population.

3. Information Barriers

As noted in our discussion of market failures, some types of information about energy efficient equipment have public good attributes while other types of information have private good attributes. Information that customers obtain to determine whether a particular innovation will work well for them generally falls into the latter category. There are many questions about new technologies that can only be resolved on a customer-by-customer basis. For example: Will the technology produce the same level of energy savings in the customer's facilities as it does in the facilities of early adopters? How reliable will the innovation prove to be in the context of the customer's home or facility? Assessments of adoption costs should include consumers' expenditures on gathering information to reduce these uncertainties, as well as the cost of bearing risks created by the new technologies.

4. Rationally High Discount Rates

Many engineering-based studies use relatively low social discount rates to value energy efficiency investments because they claim that the discount rates that consumers implicitly use to evaluate such investments are irrationally high. However, there are at lease two compelling reasons that a rational consumer would employ a high discount rate. First, some consumers face constraints on their borrowing ability, which give them high opportunity costs of capital. Second, when energy prices are uncertain, or where there is the possibility that tomorrow's energy-efficient technology will be less costly or more efficient than today's, consumers may find it in their interest to preserve their options and hold off investing in retrofits (Hassett and Metcalf, 1992). For example, a consumer may hold off purchasing insulation because if energy prices drop significantly, his investment will lose its value.

Of course, the divergence between private discount rates and social discount rates can be used to justify subsidies to energy efficient technologies. However, as noted by Jaffe and Stavins (1994c), this argument is not specific to energy policy but would apply with equal force to all forms of investment-plant and equipment, research, education, etc.

III. Literature Review

Numerous engineering studies have been cited as support for the argument that "no regrets" strategies can mitigate carbon dioxide emissions. Having carefully distinguished between market barriers and market imperfections, we now have a framework that can be used to evaluate these studies' claims.

A. Early Studies

This section reviews four widely cited studies: 1) *America's Energy Choices*, published by the Union of Concerned Scientists for a group of organizations; (2) *Changing By Degrees*, by the Congressional Office of Technology Assessment (OTA); (3) *Policy Implications of Greenhouse Warming* by the National Academy of Sciences/National Research Council (NAS), and (4) *An Alternative Energy Future* by the Alliance to Save Energy, American Gas Association, and Solar Energy Industries Association[7]

These four studies are typical of much of the early engineering literature. Each cites original sources that merely compare what consumers actually do with what consumers should do if the technology analysis is correct about costs and energy savings. Non-adoption decisions are attributed to consumer irrationality or faulty market institutions. Below, we briefly review how these studies fail to acknowledge that the choice not to adopt energy saving technologies might equally well reflect hidden costs of conservation measures described above.

1. Ignoring the Impact of Product Attributes and Information Costs

As pointed out above, we cannot make a case for policy intervention unless we account for differences in the qualitative attributes of old and replacement technologies and the cost of acquiring information about how a particular energy efficiency innovation will work on the buyer's premises. The four studies cited each need to pay much more attention to both of these categories of costs. For example, over half of the energy savings in *America's Energy Choices* come from the transportation sector, but the costs of changing transportation energy use are assumed to be nonexistent. The study also claims that it is cost

[7] Although each of these studies was prepared in 1991, their results continue to be cited and relied upon by the most current work in this area. See, for example, *Scenarios of U.S. Carbon Reductions Potential Impacts of Energy Technologies by 2010 and Beyond (1997)*, prepared by the Interlaboratory Working Group on Energy-Efficient and Low-Carbon Technologies.

effective to increase automotive fuel economy achieved by forcing motorists into smaller cars, with modifications that adversely affect perceived performance. The flaw in this study is that it ignores the value that consumers place on the amenities and performance eliminated by fuel economy standards. Similarly, this same study projects large energy savings from increased housing density — resulting from a ban on further expansion of suburbs. Such a ban would impose high costs on households that prefer suburban surroundings, yet the study explicitly assumes that those costs are zero.

2. Use of Social Rather than Private Discount Rates

All four studies assume that they can compare future energy savings to up-front costs using real discount rates of 3 to 7 percent. However, as discussed in the preceding section, these investments should be evaluated with a discount rate that actually reflects the situation in which consumers find themselves. Previous studies suggest that consumers evaluate residential energy conservation investments using discount rates in the range of 20 to 30 percent. Since these high implicit discount rates may be due to a variety of market barriers, including borrowing constraints and technological and price uncertainty, it is by no means clear that policy should be used to promote investment in energy efficient technology.

3. Failure to Account for User Heterogenity.

As pointed out above, studies that focus on an average household or firm, rather than looking at the full distribution of individuals who are potential adopters of a technology, can produce misleading conclusions about the technology's market potential. For example, *America's Energy Choices* selected a prototypical home in the Washington, DC suburbs, which is kept at an interior temperature of 65 degrees in winter and 75 degrees in summer with no reductions at night or when unoccupied. This prototype overlooks consumers whose usage patterns vary from the assumed norm. The penetration analysis used in *America's Energy Choices* also assumes that all homes will have a cost of saved energy the same as that of the prototypical home. This seemingly innocuous simplification creates a significant upward bias in estimates of cost-effective conservation.

Similarly, all of the studies used case studies of a few, potentially unrepresentative industries as a basis for assumptions about potential energy savings.

4. Failure to Account for Conservation Measures That Would Be Adopted in the Abscence of Policy Intervention.

Only the OTA study provides a benchmark against which to measure the effects of specific government policies on either the absolute size of the market for conservation measures, or the rate at which these measures could penetrate the market. The other three studies reviewed include in their estimates of energy savings changes that would clearly be adopted voluntarily by consumers faced with the prices and costs assumed in these studies.

B. Later Studies

Later analyses have taken many of these criticisms into account. For example, Koomey and Sanstad (1994) present four case studies of consumer choices among competing products or technologies, one energy efficient and one not. The four case studies contrast adoption of (1) efficient core coil versus standard core coil commercial fluorescent ballasts, (2) high efficiency versus low efficiency residential refrigerator/freezers, (3) Energy Star computers, and (4) standby power in color televisions.

Koomey and Sanstad recognize the potential importance of market barrier explanations for the slow adoption of energy efficiency technologies and attempt to control for market barriers by focusing on technologies that are well-understood and widely available. However, when these authors find that firms and individual consumers fail to adopt the four well-understood energy efficiency technologies and products listed above, they conclude that hidden market failures, rather than unexamined hidden market barriers, must be responsible.

Nichols (1994) and Levine and Sonnenblick (1994) each carry Koomey and Sanstad's analysis one step further. These two studies use survey data from a 1992 conservation program conducted by Massachusetts Electric Company (MECO) to assess whether consumers' failure to adopt energy efficient technologies before they participated in the program were due to market barriers or market failures. This program, which subsidized the installation of energy-efficient lighting for commercial and industrial customers, was chosen for study because of its exemplary measurement of energy savings and careful accounting for administration costs. Although both Nichols and Levine and Sonnenblick assume identical program costs, discount rates, and benefits accruing to the utility, they reach opposite conclusions on the presence of market failures.

Levine and Sonnenblick argue that the survey evidence indicates the presence of market failures since: (1) two-thirds of program participants said they would participate in the program in the future without any rebate and (2) over 80 percent of customers were highly satisfied with the program. In contrast, Nichols shows that when conventional business discount rates are used (rather than the utility's discount rate of 5.5 percent used for program evaluation) it takes relatively modest values of additional costs to reconcile customers refusal to buy conservation equipment unless subsidized.[8]

We believe that both the Levine and Sonnenblick paper and the Nichols paper represent a significant advance over previous work because they attempt to use data to test for the presence of market barriers. However, as discussed further below, empirical analysis of the effects of conservation programs can be useful in buttressing survey results.

C. Further Directions for Assessing the Importance of Market Failures and Market Barriers

In the two preceding subsections, we discussed how the existing literature has attempted to identify market failures that explain the slow diffusion of energy conservation technologies. This section provides directions for further research in this area. The main points of this section are summarized in Table 1. A quick review of this table indicates that in some cases, it is relatively straightforward (though by no means trivial) to rule out a particular market barrier or market failure explanation for consumer non-adoption decisions. In other cases, measurement problems are much more severe and a variety of approaches must be used to obtain useful results.

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[8] When market failures are not present, there is no way for policy (in this case a utility-sponsored conservation program) to improve on the outcome of market transactions. This assumption explains Nichols' (1994) finding that the costs of the subsidy always exceed the benefits reaped by those subsidized to adopt energy-efficient technologies. Of course, if the conservation program can eliminate some market barriers (such as reducing customer expenditures on locating and analyzing options, equipment vendors and contractors) then the harm caused by this (potentially) unneeded policy intervention will be mitigated. This harm may also be reduced if the retail price of electricity is less than its marginal cost.

Market Failure	**Tools for Assessing its Importance**
Underprovision of Information with Public Goods Aspects	Consumer surveys: econometric studies to evaluate the importance of information audits and demonstration effects on adoption decisions
Asymmetric Information in Landlord/Tenant Relationships	Evidence on how adoption decisions vary with differences in ownership patterns.
Electricity Prices Not Equal to Marginal Cost	Direct tests of the difference between electricity prices and marginal costs using publicly available data
Market Barrier	**Tools for Assessing its Importance**
Differences in Attributes Between Alternative Products	Market research surveys and/or econometric investigation to ascertain how consumers value relevant attributes
Consumer Heterogeneity	Survey usage patterns when user heterogeneity is expected to be important
Information Barriers	Consumer surveys: econometric studies to evaluate the importance of information audits and demonstration effects on adoption decisions
Rationally High Discount Rates	Begin with discount rates corresponding to potential adopters opportunity cost of capital; use benchmarking exercise relying on option valuation techniques to assess consumers' reluctance to commit to irreversible investments as a barrier.

Table 1. Assessing the Importance of Market Failures and Market Barriers

1. Asymmetric Information, Electricity Prices and Credit Constraints

Researchers can assess the impact of asymmetric information and imperfect electricity prices on conservation markets using standard econometric techniques. A useful way to analyze whether asymmetric information problems have slowed the adoption of energy-efficient technologies is to empirically test the relationship between ownership of a residential or commercial unit and investment in conservation equipment. If then tenants who lease space should be less likely symmetric information problems are important, to invest in conservation than those who own their own premises. Sutherland (1990) tests this hypothesis and finds no relationship between the ownership of commercial and industrial space and installation of conservation measures.

Researchers can also empirically test the extent to which average cost pricing of electricity causes electricity prices to diverge from the marginal cost of production. Although marginal cost data are not available for most industries, it is relatively straightforward to develop estimates of marginal cost in the electricity industry, at least in the short run. Estimated marginal costs can them be compared to regulated electricity prices, which are also publicly available.

Finally, researchers can assess whether borrowing constraints give rise to high discount rates for energy efficiency equipment by identifying consumers' asset positions, opportunity costs of finance, and their optimal choices in these circumstances. Option valuation techniques can be used to determine how consumers factor into their discount rates the value of delaying investment in an environment of uncertainty. If measured consumer valuations were below the expected value of energy savings from investing today, then further research would be needed to determine whether this seemingly irrational behavior could be attributed to market failures or the existence of other market barriers.

2. Information: Market Barriers and Market Failures

Assessing the impact of information market barriers and information market failures on the demand for specific energy efficient technologies requires both survey data and empirical work on the transforming effects of existing conservation programs. Researchers can use surveys to determine whether consumers' failure to adopt a particular energy-efficient technology arises from a lack of information about the product. If consumers reveal that they lacked information, surveys can also be used to ascertain whether the information that customers lacked had public or private good attributes, although it must be noted that the demarcation line between these two forms of information is not always clear.

Of course, such survey results will be far more credible if they are supplemented by analyses of the effect of existing conservation programs on the demand for energy-efficient technologies. In particular, studies are needed to determine whether informational programs, like home energy audits, affect the probability of consumers undertaking actual conservation investments. Researchers also need to assess the extent to which subsidized conservation programs have generated increased investment in energy-efficient technologies even after rebates associated with those programs are discontinued. Increased use of seemingly cost-effective energy-efficient technologies by participants in utility-subsidized conservation programs has often been cited as evidence supporting the existence of an efficiency gap. However, unless accounting is very accurate we cannot know whether consumers are embracing truly cost-effective technologies or whether they adopt only because program subsidies makes these technologies attractive to consumers despite their high total costs.[9]

3. Effect of Product and Consumer Attributes

As noted above, engineering studies often make simplifications that can exaggerate the market potential for the energy-saving technology. In particular, they often fail to account for all of the ways in which an energy-efficient product may differ from its conventional counterpart. In addition they may assume that all consumers have the same usage patterns as the average consumer. To address these issues, researchers should carefully screen the technologies they study to determine which product features consumers care about most. Similarly, researchers must analyze whether heterogeneous usage rates are likely to be an issue for a particular technology before making simplifying assumptions about realized savings. The research that is required to test for the importance of product attributes is essentially the same as a market analysis that would be undertaken by a company planning to launch a

[9] As pointed out in Joskow and Marron (1993a) and (1993b), researchers evaluating these programs must be sure to capture the full range of costs that customers incur when they decide whether or not to upgrade energy efficiency in response to utility-sponsored conservation programs. These costs include customer resources devoted to filling out program application forms, costs associated with installation and operation of the measure, and costs incurred due to downtime for equipment installation. Similarly, any assessment of the costs and benefits of a utility sponsored conservation program needs to capture the full range of costs incurred by the sponsoring utility in running the program.

product. The analysis should determine what consumers care about, and the implications of those preferences for the design and competitive pricing of a product. Techniques for assessing consumers' preferred attributes and their value include careful survey techniques and so-called hedonic studies that utilize statistical techniques to ascertain from actual consumer choices the implicit values that consumers place on specific product attributes.

Hedonic studies have been applied very effectively in estimating the costs associated with changes in auto size and performance associated with improvements in fuel economy. They have also been used to assess the negative attributes of alternative fuels for cars and residential energy conservation measures. However these methods work only for readily identifiable characteristics of purchases that are altered by conservation measures.[10] Marketing studies concentrating on the attributes of buildings and energy using equipment that are changed by conservation measures would be needed to more fully identify hidden costs. After hidden costs are identified, what remains could be market imperfections, whose removal might improve the efficiency of energy markets, lead to greater energy conservation and make consumers better off.

IV. Conclusions

A different focus is required for studies that seek to show that increased adoption of energy-efficient technologies can reduce carbon emissions at zero or negative net cost. Most of these studies identify promising technologies and then assume that policy instruments can costlessly induce consumers to adopt these technologies. Instead, we believe that these studies should begin by investigating the question of what market failure, if any, is responsible for the market's reluctance to adopt a particular energy-saving technology. Government intervention is unnecessary and is likely to be counterproductive when market barriers are the main impediment to acceptance of energy-efficient technologies. However, policy can be useful when well-specified market failures are responsible for consumers' non-adoption decisions.

Even when market failures are identified, policy must be applied with caution. First, no policy response is merited unless the cost of remedying the market failure is less than the benefit that could be obtained from its elimination. Market based approaches are more likely to meet this criterion than traditional "command-and-control" regulations, like efficiency standards. Unlike standards, market based policies have the potential to provide net benefits even when there are considerable technological and cost uncertainties associated with energy-efficient technologies.[11] Mandating the adoption of an apparently promising technology may prove far from a "no regrets" policy should its costs (both direct and hidden) exceed those claimed by its supporters or should actual energy savings fall short of claimed savings.

Claims that significant reductions in energy consumption can be achieved at no cost have been used to sidestep the debate about the expense of reducing carbon emissions. However, unless energy markets are characterized by market failures that can be cost-effectively eliminated, then strategies to reduce carbon emissions are likely to be quite expensive. Nordhaus (1991) summarizes the results of economic models that measure the cost of emissions reductions. He finds that while small reductions cost little, reductions of greenhouse gas emissions exceeding seventy percent of the uncontrolled level could cost 300 dollars per ton of carbon equivalent.

[10] For example, see studies by Dinan and Miranowski (1989) on costs associated with energy efficiency improvements in the residential housing market and Walls (1992) on the welfare costs of mandating natural gas vehicles.

[11] Market based policies like public information programs allow these uncertainties to be resolved by consumers. Those measures which perform as well as or better than their proponents claim will be adopted while those which prove to be relatively ineffective or excessively costly will fall by the wayside.

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