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Retrospective Examination of Demand-Side Energy Efficiency Policies

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Retrospective Examination of Demand-Side Energy Efficiency Policies

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Abstract

Energy efficiency policies are a primary avenue for reducing carbon emissions, with potential additional benefits from improved air quality and energy security. We review literature on a broad range of existing non-transportation energy efficiency policies covering appliance standards, financial incentives, information and voluntary programs, and government energy use (building and professional codes are not included). Estimates indicate these programs are likely to have collectively saved up to 4 quads of energy annually, with appliance standards and utility demand-side management likely making up at least half these savings. Energy Star, Climate Challenge, and 1605b voluntary emissions reductions may also contribute significantly to aggregate energy savings, but how much of these savings would have occurred absent these programs is less clear. Although even more uncertain, reductions in CO_2, NOx, SO_2, and PM-10 associated with energy savings may contribute about 10% more to the value of energy savings.

Key Words: energy efficiency policy, appliance standards, information, incentives, voluntary programs

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Contents

Executive Summary **1**
1. Introduction **6**
2. Appliance Standards **7**
2.1 History of State and Federal Standards 7
2.2 Federal Standards 9
3. Financial Incentives **14**
3.1 Utility Demand-Side Management Programs 14
3.1.1 Financial Incentives for Consumer Purchases 15
3.1.2 Electricity Load Management 23
3.1.3 DSM Cost-effectiveness Estimates 26
3.2 Income Tax Credits or Deductions 32
3.3 Emissions Allowances Allocated to Demand-Side Investments 35
4. Information and Voluntary Programs **37**
4.1 1605b Voluntary CO_2 Reductions 38
4.2 DOE Climate Challenge 40
4.3 Energy Star Programs 41
4.4 DOE Energy Efficient Buildings Programs 44
4.5 Partnership for Advanced Technology in Housing (PATH) 45
4.6 Industrial Energy Audits 46
4.7 State Industrial Energy Efficiency Programs 48
4.8 Product Labeling Requirement (EnergyGuide) 48
4.9 Federal Weatherization Assistance Programs 50
4.9.1 DOE Weatherization Assistance Program (WAP) 50
4.9.2 Low-Income Home Energy Assistance Program (LIHEAP) 52
4.9.3 Other Funding for Weatherization 52
5. Management of Government Energy Use **53**
5.1 Federal Energy Management Programs (FEMP) 53
5.2 Federal Procurement 54
5.3 Air Traffic Management 55
6. Synthesis **56**
6.1 Appliance Standards 56
6.2 Financial Incentives: Utility DSM 59
6.3 Information and Voluntary Programs 62
6.4 Government Energy Use 63
6.5 The Big Picture 63
6.6 Environmental Benefits 67
7. Conclusions and Implications for Future Research **70**
Tables **74**
References **86**

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Executive Summary

Energy efficiency plays a critical role in energy policy debates because meeting our future energy needs boils down to only two options: increasing supply or decreasing the demand for energy, and the latter implies demand-side energy efficiency policies. The issue is also particularly salient due to the problems of climate change, air pollution, and energy security, all of which cast an undesirable shadow over the prospect of focusing exclusively on increasing energy supply to meet a growing demand. Current U.S. greenhouse gas emissions are approximately 1.58 billion metric tons of carbon equivalent per year and are rising each year (EIA 2003d), posing a daunting challenge to policymakers attempting to grapple with the issue of climate change. Some energy efficiency advocates maintain that much of the problem could be solved, or at least ameliorated, at very low or no cost through the vigorous use of demand-side energy efficiency policies, alongside fuel switching and carbon sequestration.

Several key questions therefore immediately arise regarding the role of policies supporting energy efficiency within a portfolio of prospective energy and climate policies. First, what types of energy efficiency policies have been implemented in the United States, and how well has each of these policies worked in terms of saving energy? And, second, how much have these policies cost the public and private sector, and how cost-effective have they been?

To address these questions, we perform a comprehensive review of energy efficiency programs in the United States, with a focus on the adoption of energy efficient equipment and building practices, rather than on energy research and development. We further limit the scope of the study by omitting building codes, professional codes, and Corporate Average Fuel Economy

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(CAFE) Standards to focus on the remaining programs. We find that the applicable programs and policies tend to fall into the general categories of appliance standards, financial incentives, information and voluntary programs, and the management of government energy use.

Our review of these past energy conservation programs suggests that, taken together, the conservation programs we include likely save up to 4 quadrillion Btu (quads) of energy per year and reduce annual carbon emissions by as much as 63 million metric tons of carbon equivalent (MMtCE). These estimates typically reflect the cumulative effect of programs (e.g., all appliance efficiency standards currently in effect) on annual energy consumption. This total energy savings represents at most 6% of annual nontransportation energy consumption, which has hovered around 70 quads in recent years. Most of these energy savings come from reduced energy use associated with residential and commercial buildings (as opposed to more efficient industrial processes), so another relevant basis of comparison is total energy use in buildings, which accounts for 54% of the 70 quads of nontransportation consumption. Thus, 4 quads of energy saved represents approximately 12% of all buildings-related energy use (EIA 2003b). This also represents about a 3.5% reduction in current annual carbon emissions.

Table E-1 summarizes energy savings, costs, and carbon emissions savings for the largest-scale conservation programs, according to available information. The programs are listed in an order roughly reflecting our degree of confidence in the reliability of the estimates. Existing estimates suggest that minimum efficiency standards and demand-side management (DSM) programs have provided some of the largest energy savings—about 1.2 and 0.6 quads, respectively, in 2000. Estimates of energy savings associated with the Energy Star, Climate Challenge, and 1605b registry programs are also sizable (0.9, 0.8, and 0.4 quads, respectively, in 2000), but it is less clear what portion of these savings would have occurred in the absence of these programs. Energy savings from other programs are relatively small or unavailable. We emphasize the use of quads for comparison between programs because many of the programs cover nonelectricity reductions, which have a different heat rate than electricity.

Table E-1. Summary of Estimates of Energy Savings from Largest Conservation Programs in 2000

Program Name	Date	Energy Savings (quads)	Costs (billion $2002)	Cost-Effectiveness (billion $2002 per quad) [d]	Carbon Emissions Savings (MMtCE)
Appliance standards	2000	1.20	$2.51[a]	$3.28 [a]	17.75
Utility DSM	2000	0.62	$1.78[b]	$2.89[b] (high $19.64)	10.02
Energy Star	2001	less than 0.93	$0.05[c]	-	less than 13.80
1605b registry	2000	less than 0.41	$0.0004[c]	-	less than 6.08
DOE Climate Challenge	2000	less than 0.81	-	-	less than 12.04

[a] indicates that total costs and cost-effectiveness estimates are for residential appliance standards only while the energy savings and carbon emissions savings estimates are for commercial and residential standards combined. Residential appliance standards alone yielded approximately 0.77 quads of energy savings in 2000.

[b] Indicates only utility costs are included.

[c] indicates that only direct government administrative costs are included.

[d] Billion dollars per quad can be roughly converted to cents/kWh by multiplying by 1.166, which assumes all of the savings come from electricity using the average mix of generating facilities.

Bringing the energy savings and cost estimates together provides our measure of cost-effectiveness, defined as the annual cost of each conservation program divided by the physical energy savings it achieves.[1] We could calculate estimates of overall cost-effectiveness only for efficiency standards for residential appliances ($3.3 billion/quad of primary energy saved in 2000) and DSM ($2.9 billion/quad, including only utility costs for the energy efficiency portion of DSM).[2] If all energy savings were in the form of electricity, these estimates would translate to 3.8 cents/kWh and 3.4 cents/kWh end-use consumption for appliance standards and utility DSM respectively. The price of the energy that is saved by these programs can be used as a measure of benefits to which one can compare the cost-effectiveness estimates. While this price varies over time, as a benchmark the average price of electricity in 2000 is $6.3 billion/quad of primary energy (or 7.4 cents/kWh end-use consumption). The cost-effectiveness estimates for appliance standards suggest that its average cost of achieving energy savings compares favorably to the

[1] This definition of cost-effectiveness is adopted based on the concept of "negawatt" cost, or cost per kWh saved, and extended to include savings of other energy sources besides electricity.

[2] Note that higher dollars per quad cost-effectiveness estimates imply the program is *less* cost-effective (i.e., it costs more per quad saved).

average value of the resulting energy savings. The cost-effectiveness of DSM is similar, but includes only utility costs.

The average price we use is only a rough measure of benefits, however, and a more accurate measure would account for differences between this price and the *marginal* cost of the energy conserved. Unfortunately, a full accounting of the most appropriate measure of marginal energy cost is beyond the scope of the present study. Comparing the cost-effectiveness estimate to about $6.3 billion/quad suggests that, as a group, efficiency standards are likely to have had positive net benefits (before environmental benefits are included). DSM as a group also appears to be cost-effective, but available estimates only include utility costs, suggesting that closer scrutiny of individual DSM programs may be warranted to identify and emphasize those with high net benefits, including highly valued peak-period energy savings. Of course one must be careful about applying aggregate estimates to draw conclusions about the value of individual program elements.

Although even more uncertain, including the environmental benefits from lower emissions of carbon dioxide (CO_2), nitrogen oxides (NO_X), sulfur dioxide (SO_2), and particulate matter (PM-10) as a result of energy efficiency programs may add approximately 10% to the value of the energy savings relative to basing that value on the price of energy alone. Based on national average emissions rates and available estimates of monetized benefits, the majority (7%) of these benefits come from CO_2 reductions, with fewer benefits from NO_X (2%), and SO_2 and PM-10 (0.5% each). The inclusion of environmental benefits strengthens the case for energy efficiency programs, but does not appear to dramatically change their value based simply on energy savings.

The studies reviewed here raise several issues concerning past efforts to measure both the effectiveness and cost-effectiveness of conservation programs. Measuring the effectiveness or total energy savings from a conservation initiative or program can be problematic due to difficulties in defining the right baseline, failure to correct for free riding or the “rebound” effect, use of inappropriate discount rates, and double counting of the same energy savings attributed to multiple government programs. A major question that arises when measuring program costs or cost-effectiveness is whether or not all of the salient costs (costs to business, costs to consumers, including consumer surplus losses due to quality changes, and costs to the government) are being accounted for. Equally important, the benefits of the programs (including otherwise unaccounted

for spillovers) must be properly accounted for. All of these issues combined suggest that considerable care must be taken in interpreting existing estimates of the effectiveness and cost of energy efficiency programs.

This study reveals a lack of independent and detailed ex post academic analyses of conservation programs. Almost all available quantitative estimates are from institutions either administering or advocating the programs themselves. Several studies have presented general critiques of methods used to estimate energy savings and costs of appliance standards and of DSM programs, but there are few independent academic studies that take a detailed look at the effectiveness and the costs of specific programs. Such analyses are key to understanding the robustness of the effectiveness and cost-effectiveness estimates reported here to changes in assumptions about discount rates or assumptions about underlying growth in energy demand. Detailed analysis would be particularly important for classes of programs, such as appliance standards or utility DSM, that policymakers may plan to use more widely in the future.

The continued use of energy efficiency policies over more than two decades and the prospect of expanded and new policies on the horizon suggest that this approach to achieving energy and carbon reductions will have a lasting presence. This is particularly true if conservation programs have positive net benefits in their own right and thus yield emissions reductions at zero or negative net cost. Even if these estimates are overly optimistic, energy efficiency programs would likely be an important part of a relatively low-cost moderate climate policy, with the effect of existing efficiency programs being of a similar magnitude to what rough estimates suggest might come from a moderate carbon tax. While existing estimates indicate that the current impact of these policies is modest, it does appear that well-designed future programs have the potential to reduce energy and emissions, although the magnitude of potential reductions and the cost of achieving those reductions is an open question.

1. Introduction

Energy efficiency plays a critical role in the debate on energy policy, as the only options for meeting our future energy needs boil down to increasing supply or decreasing the demand for energy, the latter of which implies demand-side energy efficiency policies. The issue is particularly salient due to the problems of climate change, air pollution, and energy security, all of which cast an undesirable shadow over the prospect of focusing exclusively on increasing energy supply to meet a growing demand. Current U.S. greenhouse gas emissions are approximately 1,580 millions of metric tons of carbon equivalent per year and are rising annually, posing a daunting challenge to policymakers attempting to grapple with the issue of climate change (EIA 2003d). Many energy efficiency advocates maintain that much of the problem could be solved, or at least ameliorated, at very low or no cost through the vigorous use of demand-side energy efficiency policies, alongside fuel switching and carbon sequestration. This paper begins to address some of the principal questions that arise in thinking about where demand-side energy efficiency policies might fit into comprehensive energy policy by examining the past performance of energy efficiency policies and programs.

We aim to address the following questions. What policies and programs have been implemented in the past? How much has been spent on them by both the public and private sectors? What have they accomplished, and how do they compare? And, finally, what does the literature indicate about how cost-effective these programs have been? This paper is a descriptive, rather than critical, survey designed to provide an overview of the literature on demand-side energy efficiency policies. Thus, we do not attempt to analyze the existing studies in depth; however, we do attempt to present findings representing the variety of perspectives on the issue. Ultimately, this review can provide the basis for critical study of the potential for future energy efficiency policies.

The focus of this review is on adoption of energy efficient equipment and building practices, rather than on energy research and development. Even given this focus, the universe of demand-side management energy efficiency policies is quite broad. The applicable programs and policies tend to fall into the general categories of appliance standards, financial incentives, information and voluntary programs, and the management of government energy use, as summarized in Table 1. We further limit the scope of the study by omitting building codes,

professional codes, and Corporate Average Fuel Economy (CAFE) Standards to focus on the remaining programs. This review is organized into the following sections. Section 2 examines the history and literature on the effectiveness and cost of appliance standards. Section 3 examines financial incentives for energy efficient investments, first through a discussion of utility demand-side management programs, then income tax credits or deductions, and finally emissions allowances allocated to demand-side investments. Section 4 reviews the broad spectrum of information and voluntary programs. Section 5 examines the management of government energy use. Section 6 pulls together the key energy savings, cost-effectiveness, and emissions reduction numbers to provide an overview of the literature. Finally, Section 7 provides our conclusions, with lessons learned and implications for future research.

2. Appliance Standards

2.1 History of State and Federal Standards

Minimum energy efficiency standards for appliances in the United States can trace their origins to the energy crises of the mid-1970s. These energy crises, combined with environmental concerns related to new power plant siting, drove many states, particularly California and New York, to consider appliance standards to cut the growth in energy demand (Nadel 1997). This momentum culminated in the passage of the first energy appliance legislation, the 1974 California Warren-Alquist Energy Resources Conservation and Development Act, establishing the California Energy Commission with the authority to set appliance standards. Several other states quickly followed suit (e.g., New York adopted some standards by 1976), leading manufacturers to begin putting pressure on the federal government to develop national standards that would supercede the many state standards (Martin 1997).

The first federal energy appliance legislation, the 1975 Energy Policy and Conservation Act (EPCA), started slowly, by directing the National Institute of Standards and Technology (NIST) to develop standards test procedures for measuring the energy efficiency of appliances. The stage was then set for the more controversial 1978 National Energy Conservation Policy Act (NECPA). NECPA directed the Department of Energy to set mandatory standards for 13 residential household appliances and gave those federal standards pre-emption over state standards under most circumstances. In 1980, DOE proposed standards for eight products, but,

with an unreceptive administration and opposition from some manufacturers, these standards were never finalized (Geller 1997).

By 1986, the further proliferation of varying state standards led many manufacturers to seek uniform national standards to simplify product planning and marketing. The 1987 National Appliance Energy Conservation Act (NAECA) was hammered out through negotiations among manufacturers, energy efficiency advocates, and DOE (Geller 1997). NAECA established, in the law itself, national standards for 12 categories of household appliances, with strengthened pre-emption over state standards (IEA 2000). These appliances are: refrigerators, freezers, kitchen ranges, kitchen ovens, room air conditioners, direct heating equipment, water heaters, pool heaters, central air conditioners, central heat pumps, furnaces, and boilers. NAECA also contains deadlines for DOE rulemakings to update the initial standards as technology progresses. Several updates to the initial standards have occurred, most notably in 1989 for refrigerators and freezers, taking effect in 1993. In addition, further discussions between manufacturers and energy efficiency advocates have led to amendments to NAECA creating standards for other appliances. In 1988, NAECA was amended to set standards for fluorescent light ballasts, taking effect in 1994. In 1991, standards were added for clothes washers, clothes dryers, and dishwashers, also taking effect in 1994 (Geller 1997).

The next major energy efficiency standards legislation was the 1992 Energy Policy Act. The act updated existing standards and established new standards for other appliances in the law itself, temporarily superceding the DOE rulemaking process (IEA 2000). The act extended standards to a variety of lamps, induction motors, and most types of commercial heating and cooling equipment. Since the Energy Policy Act, DOE has issued several updates to the federal standards in the late 1990s, some still remaining to take effect between 2004 and 2007.

A notable feature of the history of appliance standards in the United States is the distinctive pattern of standards setting that emerged. States, particularly California, would first set new standards on unregulated appliances and, after much negotiation between industry and energy efficiency advocates, Congress would set pre-emptive national standards on those appliances. In effect, appliance standards activity shifted back and forth between the states, primarily California, and the federal government (Table 3). This pattern still continues to the present, with several states setting their own standards on appliances that the federal government does not yet regulate (Martin 1997).

In the most important case, California, there are state-wide standards on the following appliances not covered by federal standards: distribution transformers, traffic lights, commercial refrigerators/freezers, exit signs, plumbing fittings/fixtures, beverage vending machines, space heaters, and central ventilation devices (California Energy Commission 2003). Other states that have had individual state standards in the past include New York, Florida, Oregon, Virginia, Massachusetts, Maine, and Minnesota (Newell 1997). More recently, most state efforts outside of California have been usurped by federal standards, as most states do not have the resources or commitment to set their own standards (Martin 1997). Maryland has been a recent exception. On January 14, 2004, the Maryland General Assembly voted to override Governor Ehrlich's veto of a bill to set with new energy efficiency standards on a variety of home appliances. The products covered by the bill include: (1) torchiere lighting fixtures, (2) ceiling fans, (3) low-voltage dry-type transformers, (4) commercial refrigerators and freezers, (5) traffic signal modules, (6) illuminated exit signs, (7) large packaged air-conditioning equipment, (8) unit heaters, and (9) commercial clothes washers. Attempts to implement or update state standards are also under way in Massachusetts, Connecticut, New Jersey, New York, and Pennsylvania.

2.2 Federal Standards

Federal appliance standards currently cover an array of residential and commercial appliances, and standards for several more appliances are on the drawing board. Table 2 summarizes the years in which standards became effective and revised. The final rulings on the 2004–2007 standards have been completed and the standards are set to go into effect in the corresponding years, as indicated in Table 2 (Meyers et al. 2003).

Cost-effectiveness Estimates. Many studies have been published evaluating the effectiveness of appliance standards as a whole or particular appliance standards. Most of these studies are ex ante studies, performed for DOE by researchers at Lawrence Berkeley National Laboratory or the American Council for an Energy-Efficient Economy. In addition, there is an extensive body of ex ante analysis in DOE Technical Support Documents. A few studies also present estimates of ex post policy effectiveness and this section focuses on these.

One such study, Levine et al. (1994), provides cumulative estimates of appliance standards effectiveness that combine ex post and ex ante analyses. Levine et al. estimate that cumulative federal government expenditures for the appliance efficiency program total $50

million from 1979 to 1993 (in 1994 dollars), amounting to approximately $61 million in 2002 dollars. Levine et al. also estimate that the total net benefit of appliance standards for appliances sold from 1990 to 2015 is $46 billion in 1994 dollars ($56 billion in 2002 dollars), which can be decomposed into a net present cost of $32 billion for higher priced appliances and a net present savings of $78 billion due to saved energy operating costs (in 1994 dollars, discounted at 7%). The study estimates that energy savings in 1994 alone from appliance standards amounted to 0.1 quads, or almost $1 billion in 1994 dollars ($1.23 billion in 2002 dollars). The study also estimates a 1.5% to 2% reduction of total national emissions of carbon dioxide by 2015 as a result of the standards.

In a widely cited ex ante study, Geller (1995) estimates the prospective total energy savings in the year 2000 from appliance standards to be 1.23 quads. Geller et al. (2001) provides similar savings estimates based on another combined ex post and ex ante study, Geller and Goldstein (1998). Energy savings in 2000 are estimated at 1.2 quads, and the cumulative net benefit through 2030 is estimated to be $186 billion in 2000 dollars, discounted at 7% ($196 billion in 2002 dollars).

In one of the few ex post analyses of appliance standards, McMahon et al. (2000) provide retrospective estimates of energy savings, net benefits, and carbon reductions for each year 1990–1997. As only a few appliance standards took effect before 1990, cumulative estimates from McMahon et al. are roughly comparable to other cumulative estimates covering 1987–1997. McMahon et al. find cumulative energy savings of 2.0 EJ (approximately 1.9 quads) between 1990 and 1997. This provides a cumulative benefit from energy savings of $15.2 billion in 1997 dollars, discounted at 7% ($17 billion in 2002 dollars) and a reduction in carbon dioxide emissions of 29.5 MMtCE. The largest component of energy savings and emissions reductions comes in the final few years of the study; 45% of the benefits and 46% of both the energy savings and emissions reductions occur in the final two years, 1996 and 1997. McMahon et al. attribute this to the increasing percentage of appliances in use that meet the appliance standards as new appliances are bought each year. Correspondingly, the study also contains ex ante forecasts of future energy savings, net benefits, and emissions reductions from appliance standards that continue to greatly increase.

A more recent published analysis of the effectiveness of appliance standards, Meyers et al. (2003), again provides both ex post and ex ante estimates. Meyers et al. approximate the past

cost to the government of implementing the appliance standards between 1987 and 2000 to be between $200 and $250 million. The cumulative net benefit for those years is estimated to be $17 billion in 2001 dollars, discounted at 7% ($17.4 billion in 2002 dollars). This is added to some ex ante estimates to yield a cumulative net benefit from 1987 to 2050 of $150 billion in 2001 dollars ($153.6 billion in 2002 dollars) and carbon dioxide emissions reductions of 1,216 MMtCE. An additional ex ante cumulative emissions reduction estimate is provided for the years 1987–2030 and is calculated to be 964 MMtCE.

Finally, McMahon (2004) provides the underlying time-series of estimates used in Meyers et al. (2003), including the 2000 annual energy savings and aggregate cost to consumers and the government of implementing residential appliance standards. The 2000 residential annual energy savings are estimated to be 0.59 quads of electricity and 0.19 quads of natural gas, for a total of 0.78 quads. Using the 2000 average electricity price of $6.3 billion per quad and average natural gas price of $5.6 billion per quad, these energy savings translate to $4.8 billion in savings annually. McMahon estimates the total equipment cost to consumers in the year 2000 to be $2.3 billion in 1999 dollars ($2.5 billion in 2002 dollars). This time series of energy savings and cost estimates form the basis for an estimate of cost-effectiveness (see Section 6.1).

Critiques and Responses. All of the above estimates originated from the work done by researchers affiliated with Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, or the American Council for an Energy-Efficient Economy. Several more skeptical studies also exist in the literature. For example, Khazzoom (1980) suggests that mandated standards are not likely to lead to significant energy savings and, moreover, are even less likely to be cost-effective. The major rationale behind this finding is that energy efficiency improvements reduce the effective cost of energy services, leading to increased demand, and thus inducing less than proportional reductions in energy use. This effect has become known in the literature as the “take-back” or “rebound” effect. It implies that mandated standards would not yield the energy savings that ex ante estimates indicate they would, and that for some major end-uses, mandated standards may even backfire by increasing the demand for energy.

Brookes (1990) expands this claim further, using macroeconomic theory to suggest that cost-effective energy efficiency improvements may be considered a form of technological progress that improves productivity, promotes capital investment, enhances economic growth, and ultimately leads to increased energy demand. Saunders (1992) uses neoclassical growth

theory to assert that the combination of Brookes' growth effect and the take-back effect could overwhelm the energy-demand-reducing effect of increasing energy efficiency under reasonable conditions—conditions he claims may hold in the U.S. economy. Inhaber and Saunders (1994) use historical evidence to come to similar conclusions, particularly in reference to the growth effect. These arguments, while containing some merit, seem to be taken to extreme conclusions with little supporting empirical evidence.

In another skeptical paper on appliance energy efficiency standards, Hausman and Joskow (1982) provide an overview of several inherent weaknesses they feel must be considered in any evaluation of standards. First, while minimum appliance efficiencies can be controlled for by standards, actual energy use is determined by much more uncertain consumer behavior, including issues like the take-back effect. Second, uniform national standards do not seem well-suited to a country with substantial differences in weather characteristics and energy prices. Third, uniform national standards do not allow for heterogeneity in consumer tastes for energy using services and appliance choice. For instance, it may be very efficient for a consumer who uses an air conditioner for only a few days per year to purchase an inexpensive model with low energy efficiency. Fourth, when there is uncertainty about the appropriate level of standards for promoting economic efficiency, rigid standards may not be the best option, as they are difficult to adapt to new information about consumer behavior or costs. Finally, the negative impacts of appliance standards are more likely to fall on lower-income households, implying that appliance standards are a regressive policy. The degree to which these effects are empirically relevant is not explored by Hausman and Joskow.

More recently, Sutherland (1996; 1991) argues that much of the market failures theory that underlies many optimistic net benefit estimates is misguided. Instead, Sutherland contends that there is little or no evidence that such programs make consumers truly better off, simply because if such large net benefits could be gained, consumers would already be taking advantage of them. Moreover, Sutherland echoes Hausman and Joskow in suggesting that the cost burden of appliance standards would likely fall on low-income consumers who are least able to bear the burden. All of these skeptical studies claim that empirical evidence backs up their theoretical findings, although they do not typically present empirical evidence.

The only alternative estimates by the skeptics are provided by Sutherland (2003). As in his other papers, Sutherland criticizes most of the estimates in the literature for using unrealistic

discount rates and baseline energy efficiency improvement assumptions. He performs a sensitivity analysis by varying these parameters and finds that with higher assumed discount rates and greater baseline autonomous energy efficiency improvements, the net present value of appliance standards is lower. Sutherland also suggests that a 12% discount rate should be used, based on his analysis using the Capital Asset Pricing Model (CAPM).

The contentions of the skeptics are refuted in numerous papers in the literature, with various reasons provided. Grubb (1990) disputes that the take-back effect has much policy relevance, stating that the conditions under which it would be important do not apply in the case of appliance efficiency standards. Dumagan and Mount (1993) find that the take-back effect is numerically unimportant in an empirical study of the effect of efficiency improvements on residential electricity demand in New York state. Nadel (1993) reviews 42 field studies that examined the take-back effect and finds that in most cases there is little or no take-back. Stoft (1994) criticizes Sutherland's work and presents a brief analysis suggesting that appliance standards are not regressive. Howarth and Sanstad (1995) suggest that the energy market is replete with market failures, such as asymmetric information, bounded rationality, and high transactions costs, and that policy intervention, such as appliance standards, could help to correct for the market failures

Howarth (1997) presents a model to analyze the hypothesis of Brookes, Saunders, and Inhaber and Saunders that cost-effective energy efficiency investments could, in the long run, lead to greater energy use than there would be in a world without the investments, due to the take-back effect and increased economic growth. Howarth finds that improved energy efficiency would not lead to increased energy use unless these two implausible conditions hold: energy costs dominate the total cost of energy services (energy services are composed of energy costs and nonenergy costs), and expenditures on energy services constitute a large share of economic activity. Weil and McMahon (2003) provide a theoretical rationale suggesting that well-designed appliance standards are beneficial and cite several empirical studies as evidence. Nadel (2002) observes that energy efficiency improvements have stagnated for many major products in periods between when new standards take effect, suggesting that standards are successful at inducing energy efficiency. Nadel also suggests that this is accomplished cost-effectively and that some analyses, such as DOE's analyses, tend to overestimate the cost of appliance standards by not considering economies of scale in the production of energy efficient products.

Fischer (2004) presents a theoretical model illustrating that energy efficiency standards have different impacts depending on the structure of the household appliance market. If producers price discriminate and use energy intensity to help segment consumer demand, low-end appliances may be designed to under-provide energy-efficiency in order to charge purchasers of high-end appliances more for more efficient appliances. In this case, appliance standards can be welfare-improving, even for low-income consumers. If the market is perfectly competitive, it will offer the energy efficiency that consumers demand, and appliance standards would not improve welfare. Future empirical work would be needed to determine which of these cases holds.

Finally, McInerney and Anderson (1997) present a manufacturer's perspective on appliance standards. They find that past appliance standards have turned out to be cost-effective and not too much of a burden on manufacturers, but it is not clear that similar cost-effective gains can be made by forcing continued investment in energy efficiency through more stringent standards.

3. Financial Incentives

Financial incentive programs encourage energy efficiency through direct financial enticements for consumers or companies to purchase energy efficient equipment, cut their demand for energy, or invest in energy efficiency.

3.1 Utility Demand-Side Management Programs

Utility-based demand-side management (DSM) programs cover a variety of policies that allow utilities to better match their demand with their generating capacity (Gellings 1996). The term "demand-side management," when used in reference to utilities, originally meant "the planning and implementation of those utility activities designed to influence customer use of electricity in ways that will produce desired changes in the utility's load shape" (EPRI 1984). More recently, the term has become synonymous with utility energy conservation and load management programs (Chamberlin and Herman 1996). Current utility-based financial incentive programs for consumer purchases of energy efficient equipment and electricity load management fall under the auspices of utility DSM programs. Our review of DSM programs is organized in the following sections: 3.1.1 provides an overview of utility DSM programs that provide

financial incentives for consumer purchases, 3.1.2 provides an overview of utility DSM electricity load management programs, and 3.1.3 presents estimates of the cost-effectiveness of utility DSM programs.

3.1.1 Financial Incentives for Consumer Purchases

Following the first energy crisis of the 1970s, federal regulators and state public service commissions began implementing utility policies that led to the creation of utility DSM programs. The Energy Policy and Conservation Act (1975), Energy Conservation and Production Act (1976) and the National Energy Conservation Policy Act (1978) all laid the groundwork for utility DSM by providing the basis for utility conservation and load management activities. In addition, the Public Utility Regulatory Policies Act (1978) required state public service commissions to bring energy conservation considerations into their rate-making practices, furthering the impetus for utility DSM programs (EIA 1997).

Information and Loans. The first utility programs in the 1970s were most often information and loan programs, designed to educate consumers and businesses about the cost-effectiveness of energy efficiency measures and to provide low-cost subsidized financing for investments in those measures. Utilities gradually learned that education alone produced limited energy savings. In addition, most consumers were not interested in subsidized loans (Stern, Berry, and Hirst 1985). Thus utilities were led to consider programs that contained stronger financial incentives to convince consumers to make energy saving choices (Nadel and Geller 1996).

Rebates. The first financial incentive programs to be used extensively were rebate programs, with cash rebates given out by utilities to consumers who purchased designated energy efficient equipment. Rebate programs, as well as other financial incentive programs, received a considerable boost in the 1980s with the advent of integrated resource planning (IRP), also known as least-cost planning. IRP is a process in which utilities consider a broad range of resource options to meet the future energy needs of their customers. These resource options include new transmission capacity, new generation, and demand-side management. The decision of which resource to use is in theory based on assessing the costs and benefits to society of each resource. The DSM programs considered under IRP were often known as “resource acquisition”

programs because they were expected to meet the demand for energy services at a lower cost than that of acquiring generation services (Blumstein, Goldman, and Barbose 2003).

With demand-side management explicitly part of the planning process, utilities devoted considerably more resources toward achieving energy savings through DSM programs, leading to the proliferation of financial incentive programs (Nadel and Geller 1996). Nevertheless, many utilities found that rebates, while more effective than information programs, still tended to have low participation rates and did not provide the desired energy savings that the utilities (or their regulators) were seeking (Nadel, Pye, and Jordan 1994). Rebate programs also sometimes had a high rate of "free-riding," meaning that many people who received the rebates would have purchased the equipment anyway (Gehring 2002).

In sum, the results of rebate programs have been heterogeneous; some programs have been very cost-effective, with little free-riding, and others much less so. Successful programs often have featured simple application procedures, catchy marketing materials, active involvement of equipment dealers and other trade allies, free energy audits to help consumers identify conservation measures, or extensive personal marketing. In some residential appliance rebate programs, free ridership has been minimized by carefully setting how efficient an appliance must be to qualify for the program. If a high percentage of the available models qualify for rebates, there may be high gross participation rates, but also very high free ridership in the program (Berry 1990).

Comprehensive DSM. Utilities that desired further energy savings often added or switched to more comprehensive and more expensive DSM programs, such as comprehensive/direct installation programs. These programs often included an informational component and a significant financial component. For instance, many comprehensive/direct installation programs provided long-term individual assistance to help typically larger customers identify, finance, and install comprehensive packages of DSM measures (e.g., a more energy efficient cooling system combined with better insulation). Others focused on residential and small commercial customers by conducting one-time energy audits and arranging for installation of energy efficient equipment. In either case, utilities paid a large percentage of the costs of implementing the energy efficiency measures, either through rebates or other cost-sharing agreements (Nadel and Geller 1996). Aside from their cost, the more comprehensive programs

also had the disadvantage that projects with individual customers took a long time, and thus only a limited number of customers could be served each year (Nadel, Pye, and Jordan 1994).

Market Transformation and the Apex of Utility DSM. Market transformation strategies were the next solution that utilities began to emphasize by the 1990s. The term "market transformation" itself was first coined in 1992 and it describes a process of changing the market for particular types of equipment or energy services so that more efficient practices become the norm (Nadel et al. 2003). This process typically consists of a coordinated series of demonstration projects, training/informational projects, and financial incentives, with the hope that once a market is completely "transformed," there will be substantially greater energy savings as the participation or market penetration rate approaches 100%. In principle, once a market is "transformed," no additional resources are required for energy savings in that market. The downside of market transformation efforts is that they require significant organizational effort up-front and coordination of diverse parties (Geller and Nadel 1994).

The early 1990s marked the apex of utility DSM, with substantial financial incentives in place and considerable resources devoted by utilities to DSM programs in general and increasingly toward market transformation programs. By this point, DSM programs had matured into standard operating procedure for a large number of utilities. For example, in 1990, over 14 million residential, 125,000 commercial, and 37,500 industrial customers nationwide were involved in DSM programs run by over a thousand utilities, large and small (Chamberlin and Faruqui 1992). In that year, of the 1,194 large utilities with sales greater than 120 GWh in 1990, about one-third (363) reported DSM programs; many of the larger utilities had numerous DSM programs (Hirst 1992b). Utilities in the states of California, Washington, New Jersey, Rhode Island, Maine, Massachusetts, Minnesota, and Oregon led the way with the most emphasis on DSM programs (Nadel and Kushler 2000). For instance, in 1990, DSM expenditures exceeded 2% of utility revenues in Maine, Massachusetts, Rhode Island, and Wisconsin (Hirst 1994).

Golden Carrot Programs. The "Golden Carrot" Super-Efficient Refrigerator program (SERP) of the early 1990s constituted one of the first major market transformation programs. It spawned many other smaller market transformation programs with similar objectives and incentives including: Super-Efficient Apartment-sized Refrigerator Initiative (SEAR), Residential Clothes Washer Initiative, Super-Efficient Home Appliance Initiative (SEHA), High Efficiency Residential Lighting Initiative, High Efficiency Residential Central Air Conditioning

and Heat Pump Initiative, High Efficiency Commercial Ice-maker Initiative, and the Energy Efficient Traffic Signals Program. All of the aforementioned programs were coordinated by the Consortium for Energy Efficiency (CEE) and tended to utilize utility DSM or government funding to achieve their market transformation goals (CEE 2003).

In general, Golden Carrot programs refer to a category of market transformation programs where some type of significant incentive, usually in the form of a financial prize, is awarded to a company that develops a product meeting certain energy efficiency and other design criteria within a specified time period. The only large-scale Golden Carrot program to actually be implemented was the Super Efficient Refrigerator Program (SERP), which ran during the peak of utility DSM. The idea for the SERP was conceived in 1990 during discussions between the utility Pacific Gas & Electric (PG&E) and the Natural Resources Defense Council (NRDC) on how utilities could best implement market transformation DSM programs. Later that year, EPA hosted a meeting with PG&E, NRDC, the American Council for an Energy Efficient Economy (ACEEE), and the Washington State Energy Office to organize SERP, which was intended to be just the first of many Golden Carrot programs. The goal was to switch the focus of utility DSM programs from offering financial rebates to consumers who purchased energy efficient refrigerators to offering incentives to manufacturers to sell more energy efficient refrigerators. At the same time, SERP was planned to address the concern that converting refrigerators from CFC insulation to non-CFC insulation by 1995 would lead to reductions in energy efficiency. The hope was that the "golden carrot" could induce the development of a CFC-free refrigerator at least 30% more efficient than the planned 1993 federal standard that would be competitive with less efficient models in terms of style, features, look, and price (L'Ecuyer et al. 1992).

To fund SERP, 25 utilities pledged a total of $30.7 million of their utility DSM funds with the goal of creating an incentive for manufacturers to transform the market for refrigerators. A contest was held, in which the manufacturer who could achieve the most energy savings by building an energy efficient CFC-free refrigerator would receive guaranteed rebates for selling the super-efficient refrigerators in the participating utilities' service areas. Manufacturers submitted bids that included a design for a prototype of the super-efficient refrigerator to be built, a delivery schedule for that refrigerator, and a value for the desired incentive payment per refrigerator delivered. Each utility taking part would then be able to take credit for a specified

number of the winning super-efficient units shipped to its service area, providing a quantifiable energy savings to each utility. This specified number of units shipped to each utility's service area was intended to be proportional to the size of the pledge. The total value of the rebates to the winning manufacturer could equal up to the pooled $30.7 million, with the actual value depending on the number of SERP refrigerators sold in the utilities' service areas. The SERP incentive scheme was designed to reward bidders for maximum energy savings, minimum incentive payments, and commitment to a speedy delivery schedule. It also required all bidders to develop a plan for tracking where the units were sold so that each utility could be charged for the incentive payments for units sold in their service area. Utilities had the option of paying their commitment up-front or following a periodic payment schedule between June 1994 and January 1997 (Feist et al. 1994).

In October 1992, SERP received 14 bids and narrowed those down to bids from Whirlpool Corporation and Frigidaire Corporation. After final offers were submitted, Whirlpool Corporation won the competition and was awarded a contract in July 1993 to ship the new super-efficient units in 1994. These new models showed a substantial improvement over past models, with an average 20 cubic foot Whirlpool refrigerator in 1992 using $72 worth of electricity per year and the new super-efficient models using only $51 worth of electricity per year. The new Whirlpool models came in three different sizes (22, 25, and 27 cubic feet) with the smallest of those first shipped in February 1994. The two larger sizes were shipped to Whirlpool dealers in May of 1995 (Ledbetter et al. 1999).

In the winning bid, Whirlpool had originally proposed to sell 250,000 of the super-efficient refrigerator units nationwide, with an incentive payment to Whirlpool of approximately $120 per SERP refrigerator sold in participating utilities' service areas. However, by 1998 Whirlpool had pulled their line of super-efficient refrigerators after selling far fewer than had been planned, with correspondingly lower total payments made to Whirlpool. Evaluators were unable to learn the exact number of units sold, but by the end of April 1997, fewer than 100,000 had been purchased nationwide—much below expectations. According to SERP administrator David Gardner in April 1997, "Whirlpool has shipped a lot more units than have been sold" and many are "either in dealer showrooms or in somebody's warehouse" (Energy NewsData 1997).

Several possible reasons are given in the literature as to why the SERP refrigerators did not sell as well as expected. First, the SERP refrigerator model was a large, high-end model with

a relatively high price compared to most refrigerators on the market. Lee and Conger (1996) find that the particular design of the SERP tracking system led to higher prices of the SERP refrigerators than comparable models. In fact, Lee and Conger estimate that the SERP model retail prices were on average approximately $101 more than comparable units. They find this to be the case primarily because many dealers were unaware that Whirlpool would pay a $100 rebate back to them (independent of the incentive payments made by the SERP program to Whirlpool) for submitting the requisite tracking materials, causing many dealers to price the SERP models higher than Whirlpool intended them to. Many of these dealers did not return the tracking documentation at all, further contributing to the difficulty in determining the exact number of units sold.

In addition, the relatively large size and side-by-side refrigerator-freezer design of the SERP models likely played a role. Whirlpool intentionally designed the refrigerator to be large because the bid scoring system used in the SERP provided credit for the total number of kilowatt-hours saved per refrigerator, rather than the percentage of kilowatt-hours saved. For the same percentage improvement in efficiency, a larger refrigerator saves more kilowatt-hours, but it is limited in its sales potential. Compounding this, the SERP refrigerator model filled a relatively small market niche, as side-by-side refrigerator-freezers such as the SERP model were only approximately 30% of the total refrigerator market in the mid 1990s (Energy NewsData 1997). Several other reasons were also cited, such as: the lack of effective promotion of the units to both purchasers and retailers, Whirlpool's lack of communication and training for dealers and distributors, and the burden on the dealers of filling out all of the tracking paperwork (Suozzo and Nadel 1996).

While no SERP refrigerator models were produced by Whirlpool after 1998, SERP is credited with contributing to significant energy efficiency increases in other Whirlpool refrigerator models as well as modest increases in the average efficiency of all other brands (Lee and Conger 1996). However, Moezzi (1998) notes that the SERP refrigerators may not actually save energy if consumers whose purchasing decisions are based on energy efficiency are induced to buy the larger SERP refrigerators, rather than the average refrigerator on the market, which is less energy efficient but so much smaller that it uses less energy. No evaluation exists of SERP that provides ex post estimates of energy savings or cost-effectiveness of the SERP program.

SERP is recognized as being one of the first major market transformation efforts bringing together many different groups, particularly public utilities and manufacturers, to work toward the goal of transforming a market. It also is credited with demonstrating that more efficient refrigerators can be built cost-effectively, contributing to the 2001 refrigerator standard. Of the several other market transformation efforts that can trace their roots to SERP, the most notable is the Super-Efficient, Apartment-sized Refrigerator Initiative (SEAR), started in 1996 and continuing today. SEAR is more limited in scope than SERP was, focusing on public and multi-family housing, primarily in New York. A competitive bidding process for bulk orders of small super-efficient refrigerators for public housing by the New York State Power Authority is coordinated by CEE and designed to allow other sponsors to join in the order. Over 200,000 super-efficient apartment-sized refrigerators had been sold by 2003 through the program (CEE 2003). While there were originally plans for many other Golden Carrot market transformation programs, the drying up of utility DSM funds after deregulation made it more difficult for substantial financial incentives to be offered.[3]

Deregulation and Restructuring. Around the same time that utility market transformation efforts got fully underway in the early 1990s, pressure was building for deregulation of the electricity industry. With the pressure for restructuring and deregulation, prospects dimmed for funding of utility DSM programs. The 1992 Energy Policy Act that was so important for appliance standards also included a mandate requiring the Federal Energy Regulatory Commission (FERC) to devise rules for opening the transmission grids to independent power producers to sell electricity in the wholesale markets under its jurisdiction. In 1996, FERC issued Orders 888 and 889 to comply with its mandate (Brennan 1998). The Energy Policy Act was in many ways a harbinger for the wave of retail electricity deregulation, done at the state level, which is even more critical to utilities and more directly impacts their DSM programs. In 1994, California became the first state to begin restructuring its utility industry, with the goal of giving customers the choice of electricity suppliers. Soon after, many other states began considering and implementing similar restructuring and deregulation. By 2000, a total of 23 states and the District of Columbia had passed an electric industry restructuring policy.

[3] After SERP, utilities also explored a hybrid approach to encourage manufacturers to produce more energy efficient equipment: tiered rebates to manufacturers where the highest rebate tiers are for equipment that may not even be on the market yet (Nadel et al. 2003).

To prepare for the onslaught of competition, many utilities cut discretionary spending, including DSM programs. In addition, the new regulatory environment provided utilities with fewer incentives to spend money on DSM programs, as rate-of-return regulation and IRP requirements were substantially rolled back. In the new regulatory environment, price caps and greater reliance on markets for setting electricity prices created strong incentives for utilities to cut costs and seek new opportunities to increase profits by increasing electricity sales, both of which served to diminish incentives for DSM programs (Nadel and Kushler 2000). In fact, utility DSM spending declined 55% from a high of $3.44 billion in 1993 to a low of $1.55 billion in 1999 (in 2002 dollars), as shown in the second column of Table 4. Note, however, that utility DSM did not completely disappear after restructuring, as has sometimes been suggested. In 1996, for example, 600 utilities conducted over 2,300 DSM programs, involving over 20 million participants (Gellings 1996; Hirst and Hadley 1994).

Public Benefit Funds. As DSM spending plummeted in the mid to late 1990s, states began to recognize that deregulation was the leading cause, and began establishing mechanisms to stem the decline. The most common approach that regulators have taken has been to establish a public benefit fund (PBF) to fund DSM and other programs. In particular, PBFs are designed to fund energy efficiency programs, renewable energy programs, programs to assist low-income families to pay their energy bills, and a few other designated public benefit activities (Nadel and Kushler 2000). Each state or jurisdiction has its own rules for PBFs, but they are all typically funded by a per-kWh "wires charge" on the state regulated electricity distribution system (Khawaja, Koss, and Hedman 2001). These wires charges are often referred to as "systems benefit charges" or "public benefit charges." The systems benefit charge rate is usually set based on historic spending for public benefit programs, such as utility DSM energy efficiency spending. The level of the charges is typically between 0.5 and 3.0 mills per kWh (a mill being a tenth of a cent) (Nadel and Kushler 2000). A frequently cited advantage of systems benefit charges is that they are considered competitively neutral because they are added to all electricity generation (Khawaja, Koss, and Hedman 2001).

By 2000, 20 states had included specific provisions encouraging PBFs, and utility DSM spending for the past three years has been back on the rise. Market transformation programs still receive the most emphasis and, under the umbrella of market transformation programs, financial incentives for consumer purchases play a prominent role. The disastrous collapse of the energy

market in California in the winter of 2000–2001 changed the regulatory landscape in many states, leading to more emphasis on short-term and peak-load reduction energy efficiency programs, rather than longer-term financial incentives for consumer purchases. However, financial incentives for consumer purchases continue to be used often and still make up a large portion of utility DSM spending (Blumstein, Goldman, and Barbose 2003).

3.1.2 Electricity Load Management

Electricity load management programs evolved simultaneously to financial incentives for consumer purchases, with similar timing of the peak and trough of interest in them. These programs aim to limit peak electricity loads, shift peak loads from peak to off-peak hours, or encourage consumers to change demand in response to changes in utilities' cost of providing power. In essence, they serve the original definition of demand-side management, which primarily referred to changing the shape of the load curve for utilities for better reliability and peak-load reduction to avoid new power plant construction. Some examples include direct load control programs, interruptible load programs, voluntary demand response programs, real-time pricing tariffs, and demand bidding programs. A common thread in all of these load management programs is the use of financial incentives to entice consumers to take part in the programs.

Direct load control programs allow the utility to directly control the customer's equipment, interrupting the power supply during periods of peak system demand. Direct load control is typically associated with utilities periodically interrupting the power to residential air conditioning units during the summer peak demand. Customers usually receive a rebate or discount on their electric bill for providing this service to the utility. *Interruptible load programs* encompass a range of programs that involve a contractual agreement between a utility and a customer to interrupt consumer demand, either through direct control by the utility system operator or by the direct request of the utility system operator. Interruptible load programs allow large commercial or industrial customers to receive discounted 'interruptible rates' for electricity that can be stopped at any point by the utility during periods of peak demand or when the market price of electricity rises above an agreed upon rate (EIA 1997). Some interruptible load programs are designed more as an emergency load management technique for utilities than standard operating procedure, and hence are used sparingly. Thus, they are often called emergency load curtailment programs.

Voluntary demand response programs are similar to interruptible load programs, but there is no contractual obligation by customers to reduce their load. However, utilities still pay the customers for load reductions on request. Some utilities have used real-time pricing tariffs to pass on high wholesale market prices to consumers, thus encouraging the shift of equipment operation from high-cost to low-cost time periods. Real-time pricing tariffs provide customers with the flexibility to switch or reduce their load to reduce their electricity bill. They tend to be most often used by industrial customers and, to a lesser extent, commercial customers.

Demand bidding programs allow consumers to specify their own reservation bid for a certain amount of load reduction. If the market-clearing price of electricity at a given time is at or above the reservation bid price, the consumer is required to reduce electricity demand by the specified amount in exchange for a payment for the reductions. In some regions, a day-ahead market for load reductions has formed in conjunction with the day-ahead electric markets to facilitate the use of demand-bidding for companies (Energy Info Source 2003).

There are also several other types of electricity load management programs. One type consists of utility programs that fund or subsidize technologies that shift all or part of a load from one time of day to another (e.g., space heating and water heating storage systems). Another type consists of utility programs that promote consumer load reduction through the use of distributed generation in response to a signal from the utility. In the past, as part of their DSM strategies, utilities also have implemented some electricity load-building programs aimed at increasing the use of electricity at the expense of other energy sources. But, since they increase rather than decrease the consumption of energy, most analyses of utility DSM ignore spending on these programs (EIA 1997).

From the beginning of utility DSM in the 1970s, electricity load management programs were an integral part of utility DSM programs, as they provided a clear and immediate benefit to utilities in the form of reduced need for additional peak generating capacity and improved system reliability. Since then, interest in load management programs has waxed and waned as the needs of utilities changed. The early programs generally required a contractual obligation on the part of the consumer, as in interruptible load or direct load control programs.

However, utilities often had difficulty finding many participants for interruptible load or direct load control programs on a long-run basis. They found that consumers were more interested in emergency demand response programs and voluntary programs that served to

forestall imminent power shortages. Many consumers were not willing to expend the effort of tracking wholesale electricity prices or participating in these programs on a regular basis. Few consumers found it simple to just cut off their electricity demand any time at the request of the utility. For example, most manufacturers have deadlines, and stopping production at a moment's notice is not really an option. Only the largest and most flexible consumers were found to have an active interest in load management programs on a regular basis (Energy Info Source 2003).

More recently, in an effort to raise the participation rate, utilities have shifted to more voluntary demand response programs, which provide consumers the flexibility to continue or halt production at their discretion. While longer-term contractual interruptible load programs were the norm under Integrated Resource Planning in the 1980s and early 1990s, electricity restructuring clarified the wholesale spot price of electricity, leading to a shift toward shorter-term demand-side bidding and real-time pricing programs. However, all of the above categories of load management programs are still active and play an important role in utility DSM (Brennan, Palmer, and Martinez 2002).

Another important point is that load management programs may or may not lead to an actual decrease in total energy use. Many of the programs just shift the energy use from one time period to another. These programs could potentially still have positive environmental benefits if they allow for less peak generating capacity to be built, thereby decreasing resources used in construction. However, the opposite may also be true if the baseload generation is primarily coal and marginal peak generation is natural gas, in which case switching load from peak to base could lead to higher emissions. Either way, the total energy use remains the same whenever energy use is completely substitutable between time periods.

Some programs, such as direct control programs, are more likely to reduce total energy use because consumers are less likely to switch their energy use to another time. For instance, residential consumers are unlikely to use much more air conditioning at night just because they were slightly warmer during the day when the utility temporarily shut off the air conditioner. The degree of time substitutability is likely to be greater in other programs, such as interruptible load programs for industrial consumers involved in production, leading to correspondingly smaller total energy savings. Hence, utility DSM spending for financial incentives that are used for electricity load management may be useful for other utility objectives, but not primarily for the goal of energy savings.

3.1.3 DSM Cost-effectiveness Estimates

Several estimates of the costs, energy savings, and cost-effectiveness of utility DSM programs do exist. These estimates all consider utility DSM as a whole rather than breaking it down into subcategories. Utility DSM programs are a broad and easily defined category of programs, and utilities have been required since 1990 to report total utility DSM spending and energy savings from such programs to the federal government (in form EIA-861). However, it is difficult to accurately assign many utility DSM programs to separate categories because they contain elements of several types of programs—informational, financial incentives for consumer purchases, and load management. Some evidence suggests that information programs make up a small percentage of utility DSM spending and a correspondingly small percentage of energy savings (Nadel and Geller 1996). It is also probable that the bulk of energy savings are derived from financial incentives for consumer purchases, as load management programs are more likely to shift energy use than to actually reduce it.[4]

The estimates that exist for the cost-effectiveness of utility DSM tend to fall into these categories: "negawatt" cost, dollars spent by utilities on DSM, and energy savings. Negawatt cost or "negawatthour" cost is a term used since the late 1980s, typically to refer to the full life-cycle cost per kilowatt-hour saved due to a DSM program. Negawatt costs include all of the costs of running the DSM program and installing the equipment, but do not include the dollar value of the resulting savings in electricity costs. Negawatt costs are useful in comparing the cost-effectiveness of different DSM programs, but they require information or assumptions about the life cycle of the program.

Estimates of dollars spent by utilities on DSM and energy savings from DSM programs tend to be annual, and most programs have an up-front cost that generates savings extending many years into the future, making it difficult to meaningfully compare those estimates with negawatt cost estimates. While it is difficult to summarize the range of the findings succinctly, we compile the following ranges to provide some sense of the state of the literature. The findings for negawatt costs range from $0.008 to as high as $0.229 in 2002 dollars per kilowatt-hour saved, although some papers in the literature suggest that the true cost may be at the higher end

[4] Note that load management programs also only comprise a small percentage (2% to 5%) of total DSM expenditures (EIA 2003b).

of the range. While estimates for energy savings differ from year to year, cumulative energy savings from all utility DSM projects through 1998 range from 49,167 to 56,866 gigawatt-hours (GWh), with incremental or new energy savings estimated around 3,379 GWh. Estimates of utility DSM spending in 1998 range from $1,580 to $1,744 in 2002 dollars (see Table 4 and Table 5).

Negawatt Costs. Many of the papers on the cost-effectiveness of utility DSM programs focus on negawatt costs (all expressed in dollars per kilowatt-hour saved). There are numerous recent estimates available for specific regions and utilities, but for consistency, we restrict ourselves to *national* estimates. Nadel (1992) estimates the range of utility DSM negawatt costs to be between $0.014 and $0.05 per kWh in 1991 dollars ($0.019 and $0.067 per kWh in 2002 dollars).[5] In the same general range, Jordan and Nadel (1993) find a negawatt cost for industrial rebate programs of $0.019 per kWh in 1989 dollars ($0.028 in 2002 dollars). Other commonly cited estimates of negawatt costs in the early 1990s include $0.006 per kWh in 1990 dollars ($0.008 per kWh in 2002 dollars) by Amory Lovins of the Rocky Mountain Institute and $0.026 per kWh in 1990 dollars ($0.036 per kWh in 2002 dollars) by the Electric Power Research Institute (EPRI) (Fickett, Gellings, and Lovins 1990). For the purposes of general comparison, the levelized operating cost of energy from new generating units in the United States in 1991 is in the range of $0.05 to $0.10 in 1991 dollars per kWh, or $0.067 and $0.133 in 2002 dollars per kWh (Nadel 1992).

These optimistic estimates of negawatt cost, particularly the Lovins estimate, were critically examined in detail in Joskow and Marron (1992). Joskow and Marron make the case that the true cost to utilities of purchasing negawatts is substantially higher than either the Lovins or EPRI estimates due to the unaccounted-for effects of free riders, under-reporting by utilities of all relevant costs, and optimistic assumptions in the engineering analysis of energy savings that are not based on actual experience (e.g., assuming consumers keep equipment for its entire lifetime, rather than retiring it early). Joskow and Marron suggest that the actual societal cost of

[5] In this section we inflation adjust all of our negawatt cost estimates to 2002 dollars for a rough comparison. However, it must be noted that a potentially more relevant comparison may be between the nominal negawatt cost and the nominal price of energy in a particular year. On the other hand, the number of years over which the energy investment is paid off and the price of energy in all future years in which there are energy savings are also relevant considerations. Given these considerations and our desire to compare negawatt costs across studies, we choose to inflation adjust the estimates in the literature.

negawatts is underestimated by a factor of two or more on average, indicating that even the high estimate in Nadel (1992) of $0.05 per kWh in 1991 dollars may be too low.

However, after Joskow and Marron (1992), several researchers produced estimates of negawatt costs below the upper bound of the Nadel (1992) estimate. Eto et al. (1995) find a negawatt cost for all utility DSM programs of $0.032 per kWh in 1995 dollars ($0.038 per kWh in 2002 dollars). Raynolds and Cowart (2000) cite a 1994 EIA study that shows the mean reported utility cost for energy efficiency programs to be $0.029 per kWh in 1994 dollars ($0.035 per kWh in 2002 dollars). Nadel and Geller (1996) provide ranges of negawatt estimates from both the utility cost and the total resource cost perspectives based on a review of several studies. The utility negawatt cost perspective is simply based on the cost to the utility for the program, while the total resource cost perspective is based on the cost to the utility and the cost to the consumer. While not explicit, the previous estimates have tended to focus on the utility negawatt cost, with the exception of Joskow and Marron (1992). Nadel and Geller (1996) estimate utility costs per negawatt ranging between $0.025 and $0.035 per kWh in 1995 dollars ($0.030 and $0.042 per kWh in 2002 dollars) and total resource costs per negawatt between $0.04 and $0.06 per kWh in 1995 dollars ($0.048 and $0.071 per kWh in 2002 dollars). The negawatt total resource cost estimates presented in Nadel and Geller (1996) are much closer to the numbers Joskow and Marron (1992) suggested would be appropriate.

Finally, a recent ex post study on utility DSM by Loughran and Kulick (2004) attempts to resolve the issue of free riders econometrically to produce national negawatt estimates. Loughran and Kulick use EIA national data on utility DSM from 1989 to 1999 and focus on the within-utility variation in electricity sales and utility DSM expenditure. First-differencing is used to control for the unobserved heterogeneity between utilities that may affect both electricity sales and energy efficiency program adoption and size. State fixed effects are also used to control for unobserved differences between states that may affect how utilities operate. Lagged DSM expenditures are included in the model to account for previous DSM expenditures that result in energy savings in following years. Various utility-level and state level explanatory variables are also included. These techniques are intended to control for free-riding.

Given this more sophisticated estimation (in the literature, cost-effectiveness is typically cost of the program divided by total uncorrected energy savings), Loughran and Kulick find that the energy savings from DSM expenditures are smaller than utilities typically report. For the full

sample of 324 utilities, they find an average negawatt cost between $0.14 and $0.22 per kWh in 2000 dollars ($0.146 to $0.229 per kWh in 2002 dollars). For a sub-sample of larger utilities, presumably with more experience in utility DSM programs, average negawatt costs are between $0.06 and $0.12 per kWh in 2000 dollars ($0.063 to $0.125 per kWh in 2002 dollars). By comparison, the utilities themselves estimated an average negawatt cost of $0.02 to $0.03 per kWh. This result implies that 50% to 90% of the typically reported energy savings are not true energy savings, indicating that free ridership is a serious consideration.

Annual Energy Savings and DSM Spending. While not directly comparable to negawatt cost estimates, annual energy savings and utility spending estimates still provide useful information about the cost-effectiveness of utility DSM programs. One of the early papers with useful ex post energy savings and utility spending estimates is Hirst (1992c). Hirst finds that utilities saved 14,800 GWh and 17,100 GWh in 1989 and 1990, respectively. These savings cost utilities $890 million and $1,210 million in 1990 dollars for 1989 and 1990, respectively ($1,235 million and $1,678 million in 2002 dollars). Note that the annual savings in Hirst (1992c), as well as all of the papers to follow unless otherwise indicated, account for the benefits of past as well as present utility DSM programs. Several other figures in Hirst (1992c) provide a sense of the extent of energy savings and utility spending: in 1990, utility DSM expenditures accounted for 0.7% of total annual U.S. electric revenues, with a corresponding energy savings of 0.6% of the total annual energy use. Hirst (1992b) also estimates the energy savings from utility DSM programs in 1992 at 0.5% of the total annual energy use.

Faruqui et al. (1990) (EPRI) provides an estimate of utility DSM energy savings in 1990 of 32,995 GWh, which is considerably higher than Hirst's (1992c). Moreover, Hirst (1994) estimates the energy savings from 1989 through 1992 and obtains the following values: 16,300 GWh, 18,700 GWh, 23,300 GWh, and 31,800 GWh, respectively. More recently, Raynolds and Cowart (2000) estimate that the cumulative energy savings from all DSM programs over the years 1973–1998 sums up to 27 quads.

After 1990, utilities were required to submit form EIA-861 with their estimates of DSM spending and energy savings, greatly improving the reliability of the estimates from previous studies. The EIA estimates of energy savings and spending for the years 1992–2001 are provided in EIA (EIA 2003b) and reported in Table 4. Incremental energy savings refers to savings associated with new participants in existing DSM programs and all participants in new DSM

programs in a given year, annualized to indicate the effects assuming the participants had been initiated into the program on January 1st of that year. Annual effects are the total effects on energy use caused by all participants in DSM programs in a given year. Incremental effects are not simply the annual effects of a given year minus the annual effects of the prior year, since these net effects would fail to account for program attrition, equipment degradation, building demolition, and participant dropouts (EIA 1997). These numbers imply that utility DSM saved 1.6% of all electricity energy in 2001, assuming that all utility DSM energy savings are derived from reductions in electricity use. Nadel and Kushler (2000) modify the annual EIA estimates to account for some missing data and add their own estimates for some of the prior years (Table 5). Nadel and Kushler's estimate of energy savings in 1990, of 20,458 GWh, falls in between that of Hirst and Faruqui et al. In Section 6 (Synthesis), we use these estimates to develop a measure of the cost-effectiveness of utility DSM.

Note that the EIA estimates are far from perfect, as utilities self-report the energy savings. Hirst (1992a) discusses this issue and provides several reasons why the utility energy savings estimates may have problems. First, utilities may use different definitions of what counts as a DSM program. For example, some utilities may have included load-building programs in their reported data, even though the EIA explicitly stated that they should not. Second, there is no standardized method of estimating the effects of DSM programs. Some utilities may use engineering life-cycle data, which are likely to provide higher estimates than those using in-place lifetime data from surveys or field studies (Nadel and Keating 1991). Some utilities also might report energy savings at the consumer meter and others at the generator, with differences of 5% to 15% due to losses in the transmission and distribution systems. Finally, utilities often attempt to account for free riders and report the savings that can be attributed directly to the program, but some may just report total savings. The methods used to account for free riders differ among utilities as well.

On the other side of the coin, Horowitz (2004) suggests that utilities have been underreporting energy savings from commercial DSM programs in the years 1997-1999. Horowitz bases this claim on the observation that the substantial year-to-year decreases in reported commercial DSM savings are unrealistic, as decreases are only possible if equipment is put out-of-service or some other statistical adjustment is made to past year savings estimates. Horowitz asserts that savings losses are not likely to outweigh the gains unless DSM program

activity ceases and much of the earlier installed equipment begins to outlive its useful life. To adjust for this, Horowitz performs an empirical analysis to suggest that in 1997, true commercial DSM savings should be 7.7% higher than reported savings, and in 1998 and 1999, they should be 17.3% higher. These results assume that no statistical adjustment is made to improve previous savings estimates, but rather that newer estimates are underreported.

Interpreting Cost Effectiveness Estimates. There are different schools of thought in the literature about how to best interpret some of the cost-effectiveness numbers. Both Nichols (1994) and Train (1994) are critical of many of the common ways that the costs of utility DSM programs are calculated, building upon some of the criticisms of the EIA data in Hirst (1992a). Nichols particularly takes issue with the total resource cost method, suggesting that total resource cost calculations leave out three potentially important factors. First, they do not account for costs or benefits associated with effects that are not directly paid out of pocket (e.g., differences in quality, comfort, etc). Second, there are unaccounted for costs or benefits associated with program participation (e.g., time spent filling out forms). Third, there are differences between the utility's discount rate and the rate applied by participants to their own cash flows. Instead, Nichols proposes using estimates based on consumer surplus, which yield much lower net benefits than the total resource cost method. Train (1994) discusses why many of the commonly used methods of calculating net savings by utilities are overstated due to the way they handle free ridership. Train suggests an alternative means of estimating net savings based on a treatment group and control group.

Several other papers in the literature make more general statements about the theoretical cost-effectiveness of utility DSM programs that are consistent with the Nichols (1994) and Train (1994) interpretation that the costs of the programs are typically understated. Wirl (2000) provides a summary of these arguments, suggesting that utility DSM conservation programs suffer from: the rebound/take-back effect (just as in appliance standards), private information leading to adverse selection (free riders), and moral hazard (deferring conservation investment to wait for a financial incentive program). Braithwait and Caves (1994) make some of the same points, with more of a focus on how DSM rebates change consumers' behavior, a moral hazard issue that leads to the over-estimating of energy savings from the rebate program. Hughes (1992) also brings up similar points and focuses on the free ridership issue. Krietler (1991) estimates that up to 80% of energy savings in some programs at that time are from free riders, but there is

heterogeneity in programs. As discussed above, the Loughran and Kulick (2004) results imply that adjusting for free riders should reduce energy savings by 50% to 90%. These estimates of the impact of free riders add credibility to some of the arguments by Hughes (1992), Wirl (2000), and Train (1994).

However, some papers in the literature take the view that free riders and moral hazard are not major issues in most utility DSM programs, and that utility DSM energy savings are for the most part correctly estimated. Levine and Sonnenblick (1994) differ with Nichols (1994); they make the case that the total resource cost method more accurately represents actual program results and, moreover, may even underestimate the true benefits of the utility DSM program. Levine and Sonnenblick base their arguments on empirical evidence from a survey of the participants in a particular program. They find low levels of free ridership and "hidden costs" of the program (e.g., lower levels of comfort, time taken to fill out forms to participate in the program). Sanstad and Howarth (1994) also suggest that the engineering approach (i.e., total resource cost method) is the correct approach to estimate the benefits of energy conservation programs in general, but do not provide specific examples relating to utility DSM programs or the problem of moral hazard and free ridership. Eto et al. (1995) posit that additional spillover effects may balance out the effect of free riders in many cases. These spillover effects, also termed "free driver" effects, would occur if non-participants are induced to make conservation investments because of others in the program making those investments.

Finally, Gehring (2002) presents another view, suggesting that in the past, many savings estimates provided by utilities to the EIA were related more to political compromise than engineering and economic reality. But, he still suggests that DSM programs can be targeted and managed to provide energy savings to consumers and peak-load reductions for utilities. Gehring acknowledges that free ridership is an important and often unaccounted-for problem and also indicates why past utility DSM energy savings estimates were unreliable. He points out that the estimates were often based on engineering estimates and billing analysis complicated by weather, lack of end use data, and an inability to account for the impacts of human behavior.

3.2 Income Tax Credits or Deductions

Income tax credits or deductions at either the federal or the state level have occasionally been used as a policy instrument to encourage energy conservation. At the federal level, there is

no current income tax credit or deduction for residential energy efficiency investments, although there is a current federal tax deduction for individuals who purchase clean fuel or electric vehicles. This deduction went into effect in 2002 at $2,000 and will be phased out by 2006 in increments of $500 each year (IRS 2003). The Bush administration's proposed FY 2004 budget also includes tax credits for hybrid vehicles, and pending energy legislation includes tax credits for energy efficient appliances (S. 1149) and energy efficient improvements to existing homes (S. 1149 and H.R. 6) (OMB 2003).

In the late 1970s and early 1980s, there was a tax credit at the federal level for residential energy efficiency investments. The federal Energy Tax Act of 1978 (ETA78) was passed in response to the energy crises of the 1970s and provided federal income tax credits to homeowners for specified energy conservation investments. These investments included: insulating walls and ceilings, replacing furnace burners and ignition systems, and installing storm or thermal windows and doors, clock thermostats, and weather stripping. These weatherization, insulation, and similar conservation activities received an income tax credit of 15% of the total cost with a credit ceiling of $300 and the restriction that the credits could only be taken on buildings constructed prior to 1977. ETA78 also encouraged residential investment in solar, wind, and geothermal energy and those investments received a higher credit of 30% for the first $2,000 and 20% on the next $10,000, with a maximum credit of $2,600 (Walsh 1989).[6]

The conservation incentives in ETA78 were designed to expire on December 31, 1987, but were curtailed earlier in the mid-1980s as a result of tax reform legislation under the Reagan Administration. From 1978 to 1985, about 30 million claims for the conservation tax credits were filed, cumulatively amounting to nearly $5 billion (nominal dollars) in lost tax revenues or approximately $166 per claim (U.S. Congress Office of Technology Assessment 1992). The conservation tax credits were commonly perceived as relatively ineffective at inducing investment and, until recently, there has been relatively little discussion of reviving them at the federal level. Nevertheless, conservation tax credits or deductions at the state level have been in existence since before ETA78 and have continued to the present in several states. For instance, during period 1979–1985 when the federal conservation tax credits existed, Arizona, California,

[6] The Crude Oil Windfall Profits Act of 1980 increased the tax credits available for those solar, wind, and geothermal energy systems to 40%, with a maximum credit of $10,000 and no restriction on the age of the residence.

Colorado, Hawaii, Montana, and Oregon offered credits of some form and Arkansas, Idaho, and Indiana offered deductions (Hassett and Metcalf 1995). Currently, several states still have some type of conservation tax credit or deduction, including Georgia, California, New York, Hawaii, Oregon, and Montana.[7]

A small body of literature exists analyzing how effective energy conservation tax credits are at inducing conservation investment. The empirical evidence from this literature is mixed, with some of the earlier papers suggesting that tax credits are a very ineffective policy, while some of the later papers point to limited effectiveness. Carpenter and Chester (1984) take a large survey (5,366 responses) of homeowners in the western United States, and focus their analysis on behavior in response to the ETA78 federal tax credit. They find that while 86.8% of those surveyed were aware of the tax credit, only 34.5% of those aware of the tax credit actually made a claim between 1978 and 1980, and, of those who made a claim, 94% stated that they would have made the conservation investment regardless of the availability of the tax incentive. Durham et al. (1988) uses different data from the same survey to econometrically test whether state tax credits effectively encourage solar installation; the results indicate that the level of tax credits has a statistically significant effect on the probability of solar installation, with an elasticity of 0.76 with respect to the level of the tax credit.

Two other studies, Dubin and Henson (1988) and Walsh (1989) econometrically estimate the effect of tax incentives on all conservation investment. Dubin and Henson find that the coefficient estimates of tax incentives' effect on conservation investment are insignificant and very small. Moreover, Walsh finds that tax incentives not only do not induce investment, but appear to slightly decrease investment.

Hassett and Metcalf (1995) examine the studies by Dubin and Henson (1988) and Walsh (1989) and find methodological reasons for why the studies do not find a statistically and economically significant relationship between tax incentive programs and conservation investment. First, state tax programs that are deduction programs may not be correctly accounted for in some of the earlier papers, as deductions are more complex than tax credits. Second, and more important, Hassett and Metcalf (1995) state that there are individual specific effects, such as conservation "taste" factors and attributes of housing, that are likely to be correlated with the

[7] Information on these programs comes from state tax forms.

explanatory variables (i.e., whether or not a state introduces a tax credit or deduction). After controlling for these individual effects, they find a positive and significant effect of the implicit tax price of conservation deductions/credits, implying that a 10 percentage point change in the tax price for energy investment leads to a 24% increase in the probability of making an investment.

Williams and Poyer (1996) have similar econometric findings; tax credits play a statistically significant role in explaining energy conservation improvement activity. These findings, with those of Hasset and Metcalf, lend some credibility to tax credits or deductions as effective policy instruments. So, while free ridership appears to be an issue with the 1980s tax credits, the tax credits seemed to have some effectiveness in spurring conservation investment. One potential explanation is that while there were free riders who took advantage of the tax credit, there may also have been spillovers: consumers who were induced to make a conservation investment by the tax credit, but then failed to apply for the tax credit (similar to manufacturers' mail-in coupons that have low return rates) (Nadel 2004).

3.3 Emissions Allowances Allocated to Demand-Side Investments

The concept of emissions allowances allocated to demand-side investments has been discussed as a possible addition to recently proposed tradable permit systems to regulate air pollutants from electricity generation. Title IV of the 1990 Clean Air Act implemented such an approach with the Conservation and Renewable Energy Reserve of allowances, in which 300,000 SO_2 allowances were set aside. These allowances, roughly valued at a maximum of $45 million (based on the 2000 average allowance price of approximately $150 per ton if all 300,000 were awarded), were available to utilities that employed efficiency and renewable energy measures to produce early emissions reductions before their generating units became subject to the Acid Rain Program. For every 500 megawatt-hours saved through demand-side energy efficiency measures or generated by renewable energy, utilities could acquire one reserve allowance. Utilities then could use their reserve allowances in the same way they would any other Title IV allowance—use them for compliance, sell them, or bank them for future use.

In order for a utility to apply for the reserve allowances, the electricity saved must be a qualified demand-side measure or from a qualified renewable energy generating resource. The qualified demand-side measures must be noninformational (i.e., it must contain financial

incentives), implemented in a residence or facility of a utility customer, and considered cost-effective. The qualified measures must be listed in Appendix A in Title IV, which lists over 50 measures covering almost all imaginable DSM programs and renewable generating resources. For example, everything from investments in drip irrigation systems, to investments in caulking/weather stripping, to electricity generation equipment monitoring is covered. Qualified renewable energy generating resources are: biomass, solar, geothermal, and wind.

To be qualified to apply, utilities must use a regulator approved least-cost planning approach to resource planning and be subject to "net income neutrality." Net income neutrality refers to a state rate-making process requiring that energy efficiency measures be profitable or that the utility be compensated for any lost sales due to the measures. Existing utility DSM programs that meet the qualifications can be used to apply for reserve allowances; the programs do not have to be new (EPA 2003b).

In order to apply for the reserve allowances for an eligible DSM program, utilities were required to go through an extensive process with the following components: document the energy savings, document certain features of their state utility regulatory policies (e.g., least-cost planning, net income neutrality), have the state public utility commission (PUC) review and certify the application, have the state PUC certify that the utility was regulated under a regulatory scheme that qualifies, and finally, submit the application to EPA. These requirements were originally designed during the pre-restructuring era of the late 1980s and early 1990s to encourage state PUCs to adopt policies, such as least-cost planning and net income neutrality, and to encourage utility DSM and renewable energy (Kruger 2003). Utilities that were affected by Phase I of the Acid Rain Program could apply for reserve allowances for energy efficiency or renewable energy generation measures undertaken between January 1, 1992 and their compliance date of January 1, 1995. The same held true for Phase II utilities until their compliance date of January 1, 2000. After January 1, 2000, no new reserve allowances could be earned, but utilities have until 2010 to apply for reductions that occurred before the deadline (EPA 2003b).

Had the Conservation and Renewable Energy Reserve been entirely used, EPA (2003b) estimates that the 300,000 reserve allowances would represent a conversion of 150 billion kWh to energy efficiency or renewable energy, displacing 885 million pounds of SO_2, 825 million pounds of NO_X, and 225 billion pounds of CO_2. In reality, at the present only 47,493 reserve

allowances have been allocated (15.8% of the total) and it is likely that all eligible reserve allowances have already been applied for. These could be roughly valued at $7.12 million based on an average allowance price of $150 in 2000. Of the allocated allowances, 36,360 were allocated toward energy efficiency programs (76.7% of the total), with the rest going toward renewable energy generation (2003). In addition to the low participation rate, it is unlikely that the program spurred actions that would not have happened in the absence of the program. The conservative award formula, the high transactions costs of submitting a claim, and low allowance prices all contributed to the program not providing an adequate incentive to spur new DSM programs (EPA 2003c). Moreover, larger utilities were more likely to take advantage of the reserve allowances because of economies of scale in lowering the relative transactions costs; only 39 utilities have taken part in the program (Kruger 2003). In effect, the main result of the Title IV reserve allowances is that utilities that already had qualifying programs received an extra benefit from those programs.

The concept of allocating allowances to encourage energy conservation activities has continued to be floated as part of new air pollution regulation legislation. For instance, in S. 366 (Jeffords multi-pollutant bill), set-aside allowances are a part of the tradable allowance system for SO_2, NO_X, and CO_2. S. 366 would allocate no more than 20% of all SO_2, NO_X, and CO_2 allowances each year toward conservation and renewable energy activities. Any of the following would qualify: renewable generation facilities, owners of energy efficient buildings, producers of energy efficient products, entities that carry out energy efficient projects, owners of new "clean" fossil-fuel electricity generating units, and owners of combined heat and power generating facilities (Burtraw et al. 2003).

4. Information and Voluntary Programs

The information and voluntary programs we consider all attempt to induce energy efficient investment by providing information about potential energy savings or by demonstrating examples of programs that have made such energy savings. In many of the programs, firms voluntarily agree to take on goals to improve efficiency or save energy.

4.1 1605b Voluntary CO_2 Reductions

Section 1605b of the 1992 Energy Policy Act (Public Law 102-485) mandated the creation of a national inventory of greenhouse gases and a national database of voluntary reductions in greenhouse gas emissions. In doing so, Section 1605b directed the Department of Energy to establish a procedure for voluntary reporting of greenhouse gas emissions and emissions reductions by companies from the year 1987 forward, on a yearly basis. These voluntarily reported reductions in emissions could come from any possible measure, including fuel switching, forest management practices, tree planting, use of renewable energy, manufacture or use of low-emissions vehicles, greater appliance efficiency, methane recovery, cogeneration, chlorofluorocarbon capture and replacement, power plant heat rate improvement, or even nonvoluntary measures such as facility closings or governmental regulations (Public Law 102-485).

The intention of Section 1605b was to encourage companies to voluntarily reduce their greenhouse gas emissions. The database also allows companies to make public commitments to reductions in greenhouse gases in the future, giving them the opportunity to set goals and thereby improve their public image. In 1994 the 1605b program cost the Energy Information Administration (EIA) $1 million ($1.4 million in 2002 dollars) to administer. The cost then rose in 1995 to $1.4 million ($1.65 million in 2002 dollars) and eventually dropped in 1998 to $0.4 million ($0.44 million in 2002 dollars) (GAO 1998). The administrative cost leveled off from there; in 2000 it cost $0.44 million for the data collection, software updates, and report publication ($0.46 in 2002 dollars) (McArdle 2003).

While little empirical work has been done on the behavioral effect on companies of the existence and use of the voluntary reporting database, it is clear that some companies are investing the time and resources to register their emissions reductions. For instance, in 2001 228 different entities (companies or government agencies) voluntarily reported reductions in greenhouse gas emissions for 1,705 projects. The vast majority of these were either utilities or alternative energy companies, while a few were industrial companies or government agencies.

The emissions reductions reported in 2001 totaled 222 million metric tons of carbon dioxide equivalent in direct reductions, 71 million metric tons in indirect reductions, 8 million metric tons of reductions from carbon sequestration, and 15 million metric tons of unspecified

reductions. This is equivalent to a total savings of 84 million metric tons of carbon equivalent from non-carbon-sequestration reductions. Direct emissions reductions are those from sources wholly owned (or leased) by the reporting entity; indirect emissions reductions are those not owned by the reporting entity but are due to the entity's activities. For instance, both the manufacturers and owners of more efficient automobiles can register emissions reductions resulting from the ownership of those vehicles. Thus, there is a potential for double counting, but as the purpose of the program is to encourage voluntary reporting, the EIA does not prohibit double reporting. Instead, it only attempts to identify instances of potential double counting (EIA 2003e).

One important aspect of the Section 1605b voluntary reporting program is that most entities reporting tend to be affiliated with one or more other government-sponsored voluntary programs. For example, of the 1,705 projects reported for 2001, 1,412, or 83%, were affiliated with other government programs.[8] This suggests that most projects reported tended to take advantage of other government programs and were not solely induced to reduce emissions by the registering of those emissions reductions with the national database.

Including only relevant energy efficiency conservation projects not associated with any other government voluntary or utility DSM program, reductions amounting to 6.083 MMtCE were registered with 1605b in 2000 (McArdle 2003).[9] This represents an energy savings of about 0.411 quads.[10] Some percentage of these registered emissions reductions would likely have occurred in the absence of the 1605b program, but we have no way of knowing the amount that was induced and the amount that would have happened anyway. Theoretically, the emissions reductions that were induced by the program could vary between zero and 6.083 MMtCE, although common sense suggests that the true value likely falls somewhere in between.

[8] 1,041 were affiliated with the Climate Challenge Program, 180 with the Landfill Methane Outreach Program, 57 with the Climate Wise Recognition Program, 37 with the U.S. Initiative on Joint Implementation, 33 with various Energy Star programs, 17 with the EPA Green Lights Program, 16 with the Natural Gas STAR Program, nine with the Sulfur Hexafluoride Emissions Reduction Partnership, nine with the Coal-bed Methane Outreach Program, seven with Compressed Air Challenge, and six with WasteWise

[9] Registered emissions reductions from sequestration (geologic or biologic) or any other non-energy efficiency program are also excluded.

[10] Calculated using an average nontransportation emissions rate of 14.75 MMtCE/quad (EIA 2003b).

4.2 DOE Climate Challenge

The DOE Climate Challenge program is a voluntary partnership between electric utilities and DOE designed to facilitate voluntary greenhouse gas emissions reductions by utilities. The Climate Challenge program is complementary to the registration of voluntary CO_2 reductions under section 1605b of the 1992 Energy Policy Act. The program was set up in a Memorandum of Understanding signed April 20, 1994, by the DOE secretary and all of the national utility trade associations. All emissions reductions done as part of Climate Challenge are intended to be voluntary efforts that make sense on their own merits. To take part in the program, a utility must agree to three points. First, the utility must report annually to DOE on their progress. Second, the utility must be available to confer occasionally with DOE on progress to discuss potential measures that the utility may be well positioned to implement. Third, the utility must agree to one or more of six pre-specified types of reduction commitments.

The following are the six commitments that utilities could agree to. First, they could reduce greenhouse gas emissions by a specified amount below the utility's 1990 baseline level by the year 2000. Second, utilities could reduce greenhouse gas emissions to the utility's 1990 baseline level by the year 2000. Note that the first two commitments ended in 2000, and thus do not currently apply. Third, utilities could reduce greenhouse gas emissions to a particular level expressed in terms of emissions per kWh generated or sold. Fourth, utilities could reduce greenhouse gas emissions by or to some other specified level. Fifth, utilities could undertake or finance specific projects or actions to reduce greenhouse gas emissions. Sixth, utilities could make a specified contribution to any particular industry initiatives coordinated with Climate Challenge and designed to reduce greenhouse gas emissions. These six commitments are sufficiently broad so as to encompass almost all potential greenhouse gas reducing measures utilities could take, no matter what the size or structure of the utility.

DOE (2003b) suggests several incentives for utilities to participate in the Climate Challenge program: (1) national and international government officials are watching the program carefully, implying that effective voluntary efforts may prevent mandatory regulation; (2) involvement in the Climate Challenge program may lead to the allocation of possible credits in a potential future carbon policy for emissions reductions done currently with the program, which is provided under the Section 1605b voluntary registration of emissions reductions; and (3) most of the efforts that reduce emissions also tend to reduce costs or otherwise improve operations,

possibly creating "win-win" situations for utilities. In addition, publicizing emissions reductions under the Climate Challenge program can provide a public relations benefit.

As several of the commitments in the Climate Challenge program were focused on the year 2000, after that year the program stopped accepting new applicants. However, it is still run by DOE for current participants, who are regularly encouraged to make new commitments. As of 2000, there were 124 partnerships with national industry trade associations representing 651 utilities, with commitments made to reduce carbon emissions by over 47.6 million metric tons of carbon equivalent between the start of the program and the year 2000 (DOE 2003b). Many, if not most, of these commitments were fulfilled with utility DSM programs, so the energy savings and reductions in greenhouse gas emissions associated with utility DSM programs may have been encouraged in part by the Climate Challenge program.

The nonutility DSM Climate Challenge emissions reductions that were registered with 1605b in 2000 amounted to 12.038 MMtCE (McArdle 2003). This translates into an energy savings of about 0.814 quads.[11] Just as in the 1605b program, we cannot determine what percentage of these registered emissions reductions would have occurred in the absence of the Climate Challenge program. Thus, Climate Challenge-induced emissions reductions could range from zero to 12.038 MMtCE. Unfortunately, little or no empirical work has been done in the literature to analyze the effectiveness of Climate Challenge.

4.3 Energy Star Programs

Energy Star is an umbrella term encompassing a broad range of programs, all designed to encourage energy efficient investments. Energy Star began with a limited agenda in the early 1990s, after the 1992 Energy Policy Act directed EPA to implement a program to identify and designate particularly energy efficient products and to provide estimates of the relative energy efficiency of products. This legislation was designed to reward the most energy efficient products with positive publicity, thereby encouraging consumers to buy those products and other manufacturers to improve the energy efficiency of their own products. The Energy Star

[11] As with the 1605b estimates, energy savings are calculated using an average nontransportation emissions rate of 14.75 MMtCE/quad (EIA 2003b).

designation is completely voluntary and has been used by manufacturers as a selling point. Currently, EPA and DOE jointly run the voluntary labeling program.

The program started with only computers and monitors and, by 1995, expanded to include additional office products and residential heating and cooling equipment. In 1996, EPA partnered with DOE to add other product categories to the labeling program. In the following years, the Energy Star voluntary labels were extended to cover a wide array of products, with over 35 product categories, including: major appliances, office equipment, home electronics, and even new homes and commercial and industrial buildings. See Table 6 for a selected listing of products covered, their percentage energy savings over standard new products in 2000, and their market share in 2000. The definition of qualifying Energy Star products is different for each product category, but tends to include only the most efficient products on the market—a small fraction of the total market. This is not always the case, however. The vast majority of computers, monitors, copiers, faxes, VCRs, TVs, and exit signs are Energy Star-qualified.

In addition to the Energy Star voluntary labeling program, Energy Star also encompasses a range of public-private partnerships, many of which began as separate programs and were moved under the auspices of Energy Star in the late 1990s. For instance, the EPA Green Lights Program was started in 1991 to advance the adoption of energy efficient lighting systems in industrial and commercial facilities through information and demonstration activities. Similarly, the EPA Climate Wise program was created in the mid-1990s to provide information and assistance to industrial and commercial facilities to identify and implement greenhouse gas emissions-reducing activities. These programs joined the Energy Star umbrella of programs in the late 1990s due to their similarity in mission to the core Energy Star mission. Other programs include: the Green Power partnership encouraging organizations to buy renewable energy, the Combined Heat and Power partnership between the government and industry, and Energy Star Home Sealing, which helps homeowners improve the energy performance of their homes during remodeling and renovation. By 2001, Energy Star facilitated partnerships between the government and over 7,000 public and private sector organizations (EPA 2003a).

EPA has published several reports documenting the effects of Energy Star programs and a small body of academic literature analyzing these programs does exist. For instance, EPA (2002) has several estimates of energy and dollar savings of activities associated with the Energy Star programs. EPA (2002) estimates that in 2001, these activities saved more than 80 billion

kilowatt hours and avoided using 10,000 megawatts of peak generating capacity. The Energy Star label is widely known, recognized by over 40% of the American public, and over 750 million Energy Star products have been purchased through 2001. Over 57,000 Energy Star labeled homes have been constructed, providing an estimated savings from lower energy costs of more than $15 million annually. It is difficult to determine the degree to which these energy savings were induced by the Energy Star program; some likely would have occurred irrespective of the existence of Energy Star.

EPA (2002) provides estimates of the net present value through 2012 of all Energy Star-related investments made through 2001, finding energy bill savings of $75.9 billion (in 2001 dollars), incremental technology expenditures of $10.7 billion, and thus net savings of $65.2 billion. These savings are also associated with an estimated greenhouse gas emissions reduction through 2012 of 241 MMtCE.

In recent years, EPA has spent around $50 million on administering all Energy Star programs (Malloy 2003). We could find no estimates in the literature of the cost to consumers of taking part in Energy Star programs, although EPA (2002) suggests that there are no costs, as the reduced spending on energy due to Energy Star programs more than makes up for any costs incurred by participating in the programs.

A few other papers in the literature address the cost-effectiveness of Energy Star programs. DeCanio (1998) statistically analyzes data on how the Energy Star Green Lights program induces investment in energy efficient equipment and concludes that organizational and institutional factors are important impediments to such investment. DeCanio then suggests that voluntary programs such as the Green Lights program have the potential to induce energy saving investment, improve corporate performance, and reduce pollution. DeCanio and Watkins (1998) also econometrically analyze data from the Green Lights program, coming to similar conclusions.

Webber et al. (2000) contains an ex post analysis of the Energy Star labeling program up to 1999, providing estimates of cumulative energy savings, undiscounted energy bill savings, and avoided carbon emissions (Table 7). Howarth et al. (2000) reviews the Energy Star Green Lights and voluntary labeling programs, and develops a model suggesting that these programs are successful in achieving energy savings by reducing market failures relating to problems of imperfect information and bounded rationality. The findings in Howarth et al. also suggest that

these programs do not suffer greatly from the "take-back" or "rebound" effect of Khazzoom (1980) (see section on appliance standards).

4.4 DOE Energy Efficient Buildings Programs

The Department of Energy runs a suite of programs dedicated to improving the energy efficiency of buildings. These programs include: Building America, Rebuild America, the High Performance Buildings Initiative, and the Zero Energy Buildings Initiative. All of these programs work through the development of voluntary public-private partnerships.

The Building America program provides technical assistance to homebuilders and facilitates dialogue on energy efficiency between different segments of the home-building industry that traditionally work independently of one another. The dialogue and creation of teams comprised of different segments of the home-building industry is intended to apply a systems engineering approach to the construction process. The rationale for a systems engineering approach is that features of one component in a house can greatly influence others, so that looking at the construction process holistically can enable teams to incorporate energy saving strategies at no extra cost. As of 2000, there were five teams with a total of more than 150 participating companies. By 2000, over 2,000 houses in 24 states were constructed using the Building America approach (2001a).

The Rebuild America program is designed to build partnerships among communities, states, and the private sector to improve the energy efficiency of any type of building, with a focus on commercial, government, and public-housing buildings. In these partnerships, DOE offers technical assistance in the form of suggestions for energy efficiency improvements that can be made during renovations and retrofits, as well as general energy audits. A major goal of the program is to help teach local and state officials to identify prospects for energy efficient upgrades and then to provide technical assistance in the undertaking of the upgrades themselves.

DOE (2002) provides several statistics on the Rebuild America program. By the end of 2002, the program involved nearly 500 public-private partnerships and engaged in more than 800 projects in 2002 (up from 600 projects in 2001). The annual energy savings from these projects amounted to 9 trillion Btu, with energy cost savings of $131 million (in 2002 dollars). Annual

reductions in pollution reached 3,349 metric tons of SO_2, 1,576 metric tons of NO_X, and 768,239 metric tons of CO_2, as estimated from reduced electricity consumption.[12] DOE (2002) also estimates that every federal dollar invested in the program saved $18.43 (in 2002 dollars) and generated $9.38 in private energy efficiency investments.

The High Performance Buildings Initiative is a research and informational initiative in which DOE works with engineers, architects, building owners and occupants, and contractors on projects to improve the energy efficiency of new commercial buildings. The initiative primarily focuses on new office buildings. The Zero Energy Buildings Initiative is dedicated to fostering the construction of new residential homes that are super energy efficient and rely on renewable distributed generation for most of their energy needs, potentially resulting in net zero energy consumption over the year. To do so, DOE has partnered with four home-building teams to develop the concept further and provide information to homebuilders. Both the High Performance Buildings Initiative and the Zero Energy Buildings Initiative are small, relatively new programs and few assessments have been done to determine their cost-effectiveness (DOE 2003a).

4.5 Partnership for Advanced Technology in Housing (PATH)

The Partnership for Advanced Technology in Housing (PATH) program is a voluntary public-private partnership between homebuilders, product manufacturers, insurance companies, and financial companies and the U.S. Department of Housing and Urban Development (HUD). It is dedicated to improving the energy efficiency, affordability, durability, environmental sustainability, and resistance to natural disasters of residential housing. The PATH partnerships perform the following activities: provide information about the latest advances in residential housing technologies, demonstrate innovative housing projects to serve as models, promote research on new housing technologies, and attack institutional barriers to housing innovation (e.g., risk and liability concerns) (PATH 2003).

While energy efficiency is not the only objective of PATH, it is one of the primary objectives. For instance, in 2000, PATH set a goal to reduce energy use in 15 million existing

[12] Note that if these energy savings are from electricity (as opposed to fuel oil), it is not likely that this level of annual reductions continued once the Title IV cap on SO_2 was implemented.

residential homes by 30% or more by the year 2010 (HUD 2000). An independent National Academy of Sciences review of PATH in 2000 found this to be a laudable but largely unattainable goal, due to other somewhat incompatible competing goals, such as lowering the cost of housing, and the technology-demonstration/development focus of the program (National Academy of Sciences 2001). For instance, more than 80% of PATH's annual funding from Congress—$980,000 in 1998, $10 million in 1999 through 2001, and $8.75 million in 2002—is dedicated to R&D activities (National Academy of Sciences 2003).

Another National Academy of Sciences review in 2002 evaluated 56 PATH activities initiated between 1999 and 2001 and made a series of recommendations to improve the program, but the review provided no estimates of energy savings or cost savings due to the energy efficiency component of the program (National Academy of Sciences 2003). Little or no other literature exists on PATH.

4.6 Industrial Energy Audits

The Department of Energy's Office of Industrial Technologies runs two programs primarily focused on industrial energy audits: Industrial Assessment Centers (IAC) and Plant-wide Assessments (PWA).

DOE's Industrial Assessment Centers (IAC) program is one of the oldest voluntary programs, originating in 1976. The IAC program is designed to encourage improvements in industrial energy efficiency by conducting energy, waste, and productivity assessments for small to medium-sized companies. These assessments are performed at no cost to the manufacturer by teams of faculty and students from 26 university-based IACs across the United States. Students are trained in the skill of energy audits and industrial assessments while providing a free service to manufacturers. Each IAC tends to complete approximately 25 assessments per year.

The assessments themselves are made up of three components. First, the IAC team conducts a plant survey, followed by an in-depth one- to two-day audit of energy, waste, and productivity in the industrial facility. Within 60 days, the plant manager receives a report detailing the team's analysis and recommendations, along with estimated costs, performance, and payback periods for those recommendations. Finally, in six to nine months, the IAC follows up with the plant to determine which, if any, recommendations were actually implemented and the results. A database is also kept of all IAC assessments and the detailed recommendations made.

These assessments are estimated to save the average participating manufacturing facility $55,000 annually (DOE 2001b). Through 1992, DOE (1996) estimates that between 50% and 61% of the recommendations were implemented. In that same time period, implementation rates are roughly the same for all types of plants, but certain recommendations are more or less likely to be implemented. Recommendations that have high initial upfront costs and are relatively complex are less likely to be implemented (DOE 1996). Cumulatively, between 1977 and 2001, DOE estimates that almost 467 trillion Btu of energy have been saved by the IAC program, for an undiscounted cumulative savings of nearly $2 billion in 2001 dollars (DOE 2003c). The current cost to DOE to administer the program is about $7 million per year (in 2002 dollars) (Anderson and Newell 2004).

The PWA program is intended for larger manufacturers who do not qualify to receive a free IAC audit. Manufacturers are invited to submit proposals in response to a PWA solicitation, usually offered once a year. To submit a proposal, manufacturers complete a plant-wide assessment and identify potential energy efficiency investments. DOE then judges the proposal's potential energy savings and the degree to which it demonstrates cutting-edge energy efficient technologies. The energy efficient investments of accepted proposals are then partially subsidized by DOE, which provides funding of up to $100,000 per proposal. The manufacturer's cost share must be at least 50%. DOE (2003d) estimates that companies participating in assessments typically can expect to realize a minimum of $1 million in savings from energy costs, with a payback of less than 18 months.

There is little empirical literature on the cost-effectiveness of the IAC or PWA programs. In one of the few papers, Tonn and Martin (2000) present a model to describe an industrial firm's energy efficiency decisionmaking over time and then statistically analyze how IAC influences this decisionmaking process. Tonn and Martin suggest that three IAC benefits influence firms' energy efficiency decisionmaking: the direct energy assessment, the employment of a student alumni of an IAC program, or the use of energy efficiency information from an IAC website. In addition, Tonn and Martin find that all three are associated with a significant increase in the number of energy efficiency investments made by firms within a relatively short period of time.

Anderson and Newell (2004) also analyze the technology adoption decisions of manufacturers in response to IAC energy audits. They find that, while there are unmeasured project-related factors influencing the energy efficiency investments, most plants respond to the

costs and benefits presented to them in the energy audits, with a typical investment payback threshold of 15 months or less, corresponding to an 80% or greater hurdle rate. They also find that plants reject about half of the recommended projects, with the stated reasons primarily reflecting economic undesirability.

4.7 State Industrial Energy Efficiency Programs

In addition to the Department of Energy, many states and regional bodies have industrial innovation and competitiveness programs, many of which are specifically dedicated to industrial energy efficiency improvement. Approximately 300 of these programs exist, with some of the most well-known programs found in the states of Iowa, New York, Texas, and Wisconsin.

These programs vary in scope and focus. For instance, the Iowa Energy Center focuses on agriculture and energy audits, while the Energy Center of Wisconsin and the LoanSTAR program in Texas focus more on demonstration projects. The New York State Energy Research and Development Authority (NYSERDA) focuses more on industrial energy efficiency. In general, the state programs are active in the areas of information dissemination, energy auditing, demonstration, and R&D of energy efficient industrial technologies, much like the DOE industrial information programs. Many of these state programs have partnerships with the DOE Office of Industrial Technologies to coordinate activities (Interlaboratory Working Group 2000).

Since there is such a broad range and large quantity of state programs, there is little in the literature on the cost-effectiveness and energy savings from these programs as a whole.

4.8 Product Labeling Requirement (EnergyGuide)

In response to a directive in the Energy Policy and Conservation Act of 1975, the Federal Trade Commission (FTC) issued the Appliance Labeling Rule, 44 FR 66466, in November 1979. This Appliance Labeling Rule created the well-known “EnergyGuide” label, providing information to consumers about the energy efficiency of major household appliances. The following categories of appliances are covered: refrigerators and refrigerator-freezers, freezers, dishwashers, clothes washers, water heaters, room air conditioners, furnaces, and central air conditioners (IEA 2000).

On the standardized EnergyGuide label for each appliance, manufacturers are required to include an energy consumption or energy efficiency figure and a "range of comparability." This range allows consumers to compare the efficiency of the particular model with other similar models by indicating the highest and lowest energy consumption for similar models in the market. The EnergyGuide label also contains an estimate of the yearly cost to operate the model, based on national averages.

To be in compliance with the Appliance Labeling Rule, manufacturers must annually report for each of their appliances the estimated energy consumption or energy efficiency rating calculated from DOE test procedures. Each year, FTC analyzes the range of comparability for each appliance and, if the upper or lower limit changes by more than 15%, a new range is devised (FTC 2003).

In contrast to the Energy Star voluntary labeling program, the EnergyGuide labeling program is mandatory, but both programs have a similar informational purpose. Put simply, both are intended to convince consumers to take energy efficiency into account in their appliance purchasing decisions. However, little analysis has been done in the literature to determine whether consumer behavior is significantly influenced by the EnergyGuide labeling program. Anecdotal evidence presented in Weil and McMahon (2003) suggests that labeling programs such as EnergyGuide can successfully induce energy savings. Newell, Jaffe, and Stavins (1999) find that with product-labeling requirements in effect, energy price increases are more effective at encouraging manufacturers to offer more energy efficient products.

However, some of the literature on utility DSM informational programs also mentions labeling programs in general as a fairly ineffective policy tool (e.g., Levine et al. (1994), and Thorne and Egan (2002)). This could be attributed in part to a lack of compliance at the retail level with the EnergyGuide labeling requirements. For instance, in 2001, the FTC inspected 144 showrooms in the United States and found that 70 of them were not in compliance with the mandated EnergyGuide labeling requirement (FTC 2001). Thorne and Egan (2002) suggest a redesign of the EnergyGuide labels and discusses international programs that have been more successful.

4.9 Federal Weatherization Assistance Programs

Federal weatherization assistance programs were some of the first federal energy conservation programs. These programs have the overarching purpose of assisting low-income households with their energy bills, primarily through the financing and implementing of residential energy conservation investments, resulting in corresponding energy savings. Low-income families typically spend larger fractions of their income on energy and, at the same time, low-income residences are often older and in greater disrepair than those of higher-income groups, presenting opportunities to assist low-income families while "picking the low-hanging fruit" in residential energy conservation.

The now-defunct Community Services Administration (CSA) oversaw the first federal weatherization program between 1974 and 1981, formed in response to high energy bills caused by the Arab oil embargo of 1973. It consisted of local grants to assist low-income households weatherize their homes, and also provided some subsidies to assist low-income households pay their energy bills (U.S. Congress Office of Technology Assessment 1992). Currently, two major federal residential weatherization programs exist, the DOE Weatherization Assistance Program (WAP) and the Department of Health and Human Services Low-Income Home Energy Assistance Program (LIHEAP). These programs have been a major focus of past federal efforts to conserve energy in buildings, and the combined budgets of the two programs have consistently been higher than any other federal program funding aimed at energy conservation in buildings.

4.9.1 DOE Weatherization Assistance Program (WAP)

WAP was authorized under Title IV of the Energy Conservation and Production Act (Public Law 94-385) in 1976 to fund weatherization measures for low-income households to reduce their energy use. WAP prioritizes services to low-income families with children, the elderly, people with disabilities, and low-income households with a high energy burden. The program works through partnerships between DOE and state and local agencies in which DOE provides program grants. Currently, there are over 970 local agencies that receive grants for work in every state, the District of Columbia, and on Native American Reservations. Since 1976, around 5 million households have received weatherization services out of the nearly 27 million

eligible households. Each state sets its own criteria for eligible households, with the minimum criterion being households with incomes below 125% of the poverty line.

The program is completely voluntary, and each local agency determines to whom they should be offering the program services. These services begin with an energy audit of the home, followed by implementation of the most cost-effective measures. These measures include: sealing ducts, tuning and repairing heating and cooling systems, mitigating air infiltration, and installing insulation. In addition, the weatherization crews perform a health and safety audit of the house to test for problems such as: gas leaks, electrical system safety, moisture damage, and unsafe heating and cooling systems. The crews will also implement solutions to any health and safety issues (Schweitzer and Eisenberg 2003).

WAP appropriations are set by Congress on a yearly basis and have varied throughout the program's lifetime (Table 8). In FY 2002, WAP weatherization funding represented 40% of the total federal investment in weatherization. To allocate the funds, DOE first sets aside no more than 10% of the total funding to states for training and technical assistance at the state and local levels. The remaining funds are distributed to states according to an allocation formula that was last revised in 1995 before a significant funding cut for the program in FY1996. The allocation formula first sets aside a fixed base allocation that differs by state, in order to prevent large swings in funding that could disrupt programs. The remaining funds are allocated to states based on the following three factors: low-income population, climatic conditions, and residential energy expenditures by low-income households (WAP 2003).

A few figures are provided in the literature that help gauge the cost-effectiveness of the program. Berry and Schweitzer (2003) perform a meta-evaluation of WAP, bringing together many smaller surveys to estimate that the average net savings of the roughly 100,000 homes weatherized annually is 29.1 million Btu per home per year, corresponding to a total fuel reduction of 21.9%. The promotional material for WAP expands this estimate further, claiming that WAP reduces national energy demand by the equivalent of 15 million barrels of oil per year on average. In addition, WAP estimates that it reduces annual carbon dioxide emissions on average by 0.85 metric tons of carbon for homes heated with natural gas and 0.475 metric tons of carbon for homes heated with electricity. The avoided energy costs to the 5 million households weatherized in the program since its inception totaled approximately $1 billion during the winter of 2000-01 (WAP 2003).

4.9.2 Low-Income Home Energy Assistance Program (LIHEAP)

LIHEAP is an outgrowth of the Community Services Administration Crisis Intervention program, part of CSA's low-income energy assistance program, which ended in 1981. The Department of Health and Human Services' LIHEAP was authorized by Title XXVI of the Low-Income Home Energy Assistance Act of 1981, with the primary aim of assisting with the heating and cooling bills of eligible low-income households. To achieve this goal, states are provided block grants to assist low-income households through direct home heating and cooling assistance, energy crisis assistance, and home weatherization. Home energy assistance consists of assistance in the form of cash, vouchers, coupons, or two-party checks to eligible households that can be paid to either landlords or home energy suppliers to defray the cost of energy bills. Energy crisis assistance provides cash, shelter, emergency supplies, or supplemental heating sources to households without heat or in imminent danger of having their fuel supplies terminated. The allocation to each state is a product of complex political compromise, but is vaguely based on the same principles as the WAP state allocations (Kaiser and Pulsipher 2002).

States can allocate up to 15% of their LIHEAP funds for home weatherization programs, and in most typical years, states spend on average around 10% of their LIHEAP funds on weatherization. Total LIHEAP funding has generally ranged over the years between $1 billion and $2 billion (2002 dollars) with a few years in the mid-1980s having higher levels. For example, in FY 2002, LIHEAP had a total allocation of approximately $1.7 billion and contributed $201 million (approximately 12%) toward weatherization activities (LIHEAP 2003). Note that the heating/cooling assistance and energy crisis assistance are effectively energy subsidies for low-income households and are more likely to *increase* energy consumption than to decrease it. Thus, the vast majority of the funding for LIHEAP serves to increase energy consumption and the program, in net, likely has a positive effect on energy consumption.

4.9.3 Other Funding for Weatherization

There is some other funding available for low-income household weatherization activities. Beginning in the 1980s, a Federal Petroleum Violation Escrow (PVE) Fund was established from legal penalties assessed against oil companies for violating price controls. By 2002, most states had exhausted their PVE funds, so that the total in FY 2002 amounted to only $6.9 million. However, even at their peak, PVE funds were never as large a funding source for

weatherization as WAP or LIHEAP funds. Other funding for low-income housing weatherization activities comes from utility DSM programs, state general fund revenues, property owner contributions, and rehabilitation grants. This "other" funding category was estimated in FY 2002 to total $122 million (LIHEAP 2003).

Together, WAP, LIHEAP, and the other weatherization funding in FY 2002 is estimated to have allowed the weatherization of 186,779 homes, with past years tending to range around 200,000 to 250,000 homes (LIHEAP 2003). It is difficult to determine the cumulative energy savings and the cost-effectiveness from these weatherization activities, due to the variety of programs.

5. Management of Government Energy Use

The Federal government is the nation's largest energy consumer, and has considerable influence on markets for energy efficient products as a consumer that spends around $200 billion annually on products and services. Thus, several programs and regulations have been implemented to promote the conservation of energy by federal government agencies.

5.1 Federal Energy Management Programs (FEMP)

The Department of Energy's Federal Energy Management Program (FEMP) was established in 1973 with a mandate to encourage effective energy management in the federal government in order to save taxpayer dollars and reduce emissions. FEMP's services can be grouped into four main categories: financing, technical assistance, outreach, and policy.

FEMP assists government agencies with acquiring financing for energy efficient investments through methods such as: Utility Energy Service Contracts (UESCs), Energy Savings Performance Contracts (ESPCs), utility rebates, and public benefits funds. With UESCs, utilities typically finance the capital cost of an energy conservation project in return for a contract in which the utility is repaid for the costs of the project over the term of the contract from the cost savings generated by the project. ESPCs are similar in concept to UESCs, but a contractor pays the upfront capital cost of an energy conservation project in return for payments over the term of the contract from the project's subsequent cost savings. There is a streamlined version of ESPCs called Super ESPCs, which are umbrella contracts with energy

service companies (ESCOs), allowing agencies to undertake multiple energy projects under a single contract. FEMP helps government agencies find financing through utility rebates and public benefits funds by explaining the procedure through which financing can be acquired via these methods.

FEMP also provides technical assistance directly to government agencies by helping federal energy managers identify, design, and implement new construction and facility improvement projects. To do so, FEMP offers services such as energy audits for government buildings and analytical software tools that help agencies choose the most effective energy and water project investments. The outreach services FEMP provides are mostly informational and recognition services, in which agencies are informed of the latest energy saving strategies and are rewarded for exemplary energy management leadership. The policy services of FEMP primarily consist of reporting on agencies' progress annually, managing interagency working groups, and otherwise coordinating across agencies to meet national goals. For instance, Executive Order 13123 requires all federal agencies to reduce energy use in federal buildings by 35% from 1985 levels by 2010 (FEMP 2003).

The FEMP budget for FY 2002 was $24.8 million. More than half of that funding was allocated toward project financing assistance ($8.7 million), and technical guidance and assistance ($7.9 million) (FEMP 2002). Little analysis has been done to determine the aggregate benefits and the cost-effectiveness of this funding. However, FEMP has published a few statistics. FEMP (2002) estimates that between FY 1985 and FY 2001, the government has reduced its buildings energy intensity by 23%, with six agencies achieving reductions of more than 20% in buildings energy use per gross square foot in that time. With total federal energy use in buildings of about 0.3 quads, this amounts to an annual savings of about 0.07 quads relative to a 1985 base. As there have been significant changes in government energy use (e.g., military base closings), it is unclear whether these intensity reductions are due to technological improvements or simply a change in the breakdown of federal energy use. Furthermore, it is unclear how much of this improvement would have happened in the absence of FEMP.

5.2 Federal Procurement

The federal government is one of the largest buyers in the world for many products, purchasing at least 10% of all energy using products in the United States. Executive Order

13123, signed by President Clinton in 1999, requires that federal agencies select "life-cycle cost-effective" Energy Star products over any other products (1999). For product categories that do not have Energy Star labels, agencies are required to select products in the upper 25% of energy efficiency, as designated by FEMP. FEMP also facilitates federal procurement of energy efficient products through interagency outreach and training, and the publication of "Energy Efficient Recommendations" for more than 30 product categories of energy using products often purchased by federal agencies. One of the many programs under the auspices of Energy Star, the Energy Star Purchasing Program, also encourages similar policies at the state and local government level.

Harris and Johnson (2000) estimate the potential energy, cost and CO_2 savings from the federal energy efficient procurement policies (i.e., Executive Order 13123). The estimates provided are ex ante, for the year 2010, but they are some of the only estimates provided in the literature. Harris and Johnson estimate that by 2010 the combined savings from federal energy efficient procurement policies will range from 11 to 42 trillion Btu/year, representing a reduced federal energy cost of $160 to $620 million per year, or approximately 3% to 12% of the 2000 energy use in federal buildings. Harris and Johnson also project the annual savings in 2010 from energy efficient purchasing by states, local governments, and schools as a result of the Energy Star Purchasing Program to range from 40 to 150 trillion Btu/year. Combined, these savings are estimated to translate into a reduction in annual CO_2 emissions of about 2.4 to 8.6 million metric tons of carbon in 2010 or about 0.1% to 0.5% of projected U.S. carbon emissions of approximately 1.8 billion metric tons of carbon equivalent (EIA 2003a).

5.3 Air Traffic Management

A joint program by EPA and the Federal Aviation Administration (FAA) is designed to reduce the demand for energy and the corresponding emissions by optimizing the traffic control system to reduce the time planes spend waiting "on line" on the ground and circling around airports while waiting for landing spots. The program, started in 1997, is known as CNS/ATM (Communications, Navigation, and Surveillance/Air Traffic Management) and involves changing flight procedures and installing a network of technologies to more precisely locate aircraft (Interlaboratory Working Group 2000). FAA estimated in an ex ante study that, by optimizing

flight patterns, the program would reduce aircraft energy use by up to 6%, or 10 billion pounds of fuel by 2015 (Liang and Chin 1998).

6. Synthesis

Assessing the overall and comparative effectiveness and cost-effectiveness of the collection of energy conservation programs reviewed here is a nearly impossible task given the limitations of existing information and the incompatibility of data from different programs. We nonetheless attempt the impossible by combing the literature for estimates of annual energy savings and the annual costs of obtaining those savings for 2000 or a proximate year. Where possible, we report the cost-effectiveness of different conservation programs in dollars per quad of energy saved. In the case of utility DSM, where we have information from multiple sources, we report a range of cost-effectiveness estimates from the literature. The cost-effectiveness estimates can then be compared to the value of the energy saved, including any additional social value associated with reduced energy related environmental harm. In some cases we develop our own estimates of annual energy savings or costs based on related measures (multi-year program costs, for example) from the literature. We also report estimates of carbon emissions avoided due to the reported energy savings. These estimates are presented in Table 9; the underlying sources and assumptions, including critical assessment thereof, are the subject of this section. Table 10 summarizes the sources used to create Table 9.

6.1 Appliance Standards

Gellar et al. (2001) present a combined ex ante/ex post assessment of federal appliance standards and estimate that appliance standards saved a total of 1.2 quads of energy in 2000, approximately equal to the Gellar (1995) ex ante prediction for 2000. McMahon (2004) provides a time series of annual estimates of energy savings and equipment costs for residential appliance standards between 1985 and 2001. For instance, McMahon estimates 2000 residential energy savings of 0.77 quads.

On the cost side, it is important to recognize that the equipment cost of energy efficiency investments in a particular year will yield energy savings several years into the future. In other words, energy savings in 2000 can be thought of as the result of a stream of past investments in equipment subject to the standards that were in effect when those investments were made. The

annualized economic cost in 2000 of this stream of past investments includes the annual depreciation plus financing costs. Unfortunately, the published literature, which in some cases provides estimates of annual expenditures on energy efficient equipment, provides no estimates of the annual economic cost in 2000 as we have defined it.

In order to develop an estimate of annual economic costs in 2000, we use the perpetual inventory method, an approach commonly used for the purposes of estimating the capital portion of annual production costs (Jorgenson, Gallop, and Fraumeni 1987). This method accounts for additional expenditures by consumers due to appliance standards as an investment that yields benefits in future years that depreciate over time.

First, we derive a "capital stock" by accumulating the annual equipment expenditures due to appliance standards from 1985, the year of the first standards, to 2000. This calculation requires an estimate of the annual physical rate of depreciation of DSM capital and the annual cost of capital (i.e., real discount rate). The depreciation rate is assumed to be 15%, based on the official depreciation rate for household appliances used in the national income accounts by the Bureau of Economic Analysis (Fraumeni 1997).

Specifically, the perpetual inventory formula indicates that cummulative appliance standard capital in year t equals incremental equipment expenditures in year t + (1-0.15)*(total capital in year t-1). This provides a time series of the accumulated value of appliance standard capital. To estimate the annual cost of using that capital in a given year, we multiply the stock measure for that year by the rental price of capital. The rental price of capital is the sum of the annual depreciation rate (15%) and the discount rate, which is assumed to be 7% (as in Levine et al.), for a total rental price of capital of 22%.

This implies a cost-effectiveness of approximately $3.3 billion per quad or 3.8 cents per kWh end-use consumption if all savings were in the form of electricity, using an estimate of 0.77 quads saved by residential appliance standards in 2000.[13] Note that the cost to the government of implementing the residential standards is estimated by Meyers et al. (2003) to be $200–250 million between 1987 and 2000, or about $15 million a year—orders of magnitude lower than the rough estimate of cost to consumers.

[13] If we use a lower real discount rate of 4%, which is near the low end of the discount rates used by utilities in evaluating DSM investments, we find that cost effectiveness is $2.8 billion per quad or 3.3 cents per kWh.

We calculate carbon emissions reductions associated with appliance standards by multiplying total energy savings times the average carbon emissions rate for nontransportation energy use in 2000 of 14.79 million metric tons per quad (EIA 2003b). The computed value in 2000 is 17.8 million metric tons of carbon equivalent for all appliance standards and 11.4 million metric tons of carbon equivalent for residential appliance standards.

All of the estimates reported here are drawn from or based on the small, predominantly engineering-based, quantitative literature evaluating appliance standards. A major problem with these studies is that they typically ignore behavioral responses to the program and their effects on energy savings and costs. These behavioral responses could result in actual energy savings that are either higher or lower than estimated energy savings, but typically will result in higher costs due in part to the failure to account for the costs of limiting consumer choices. Another complicating factor is identifying the baseline level of energy consumption in the absence of the standards. In addition, the discount rate used for computing the present value of energy savings is typically assumed to be 7%, which is lower than the opportunity cost of funds for many consumers. Increasing the discount rate from 7% to 14%, for example, significantly lowers the present value of a 15-year stream of constant benefits. Several authors, including Hausman and Joskow (1982), criticize the engineering approach to evaluating appliance standards, suggesting that energy savings are often overestimated and costs underestimated, but none of these critical studies offers alternative estimates of their effectiveness or cost-effectiveness.

Appliance standards do appear to yield positive net benefits to consumers on average. The average electricity price in 2000 was $6.3 billion (in 2002 dollars) per quad of primary energy[14], while the cost of residential appliance standards was just under $3.3 billion per quad. Even if unaccounted for costs of appliance standards are so large as to be almost equal to those included in the study, *or* if actual energy savings are roughly half of what is estimated, the package of appliance standards would still yield positive net benefits on average. Adding in the positive environmental benefits of reduced electricity consumption would strengthen the argument that the benefits of appliance standards were worth the cost.

[14] About three-quarters of energy savings from energy efficiency standards have come from electricity in recent years and one-quarter natural gas. We use an average electricity price to value these energy savings, which makes the cost-effectiveness of efficiency standards look somewhat better than it otherwise would because the average price of delivered natural gas is lower than the average electricity price.

6.2 Financial Incentives: Utility DSM

The only financial incentive programs for which we were able to find estimates of energy savings were utility DSM programs.[15] EIA survey data indicate that the total annual energy savings from energy efficiency utility DSM programs in 2000 was 52,827 GWh(EIA 2003c). Based on an average delivered heat rate of 11,660 Btu per kWh, this estimate equates to 0.616 quads of primary energy saved.[16] The annual cost associated with all the DSM programs contributing to these energy savings in 2000 is not reported by EIA. Instead, for each year of the survey, EIA reports the incremental costs to utilities of new or expanded DSM programs in that year. These utility expenditures typically are expected to yield energy savings for many years into the future, so for any one particular year, the costs of the energy savings are distributed over several previous years. Thus, we again use the perpetual inventory method, just as was done for appliance standards.

First, we derive a DSM expenditure "capital stock" by accumulating incremental DSM expenditures from 1989 to 2000. As with appliance standards, the accumulation of this capital stock requires an assumed annual physical rate of depreciation of DSM capital and annual cost of capital (i.e., real discount rate). In addition, for utility DSM, we must also assume zero initial capital stock in 1988.[17] The depreciation rate is assumed to be 11%, based on the official depreciation rate for general private industrial equipment used in the national income accounts (Fraumeni 1997).[18] The total annual cost of capital (or real discount rate) is again assumed to be 7%, giving a total rental price of capital of 18%.

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[15] EPA also reports energy savings associated with the Conservation and Renewable Energy Reserve (CRER) under Title IV of the Clean Air Act. However, the energy savings from these programs typically overlap to a large extent with existing utility DSM programs (as having an integrated resource planning program is a prerequisite for participating in the CRER) and thus we do not count these energy savings separately.

[16] The heatrate accounts for both energy losses in the generation process and energy losses due to transmission of electricity. Thus we convert kWh of reduced final energy consumption to quads of reduced primary energy consumption.

[17] If initial DSM capital were in fact greater than zero, this assumption would lead to an understatement of costs, although the importance of this assumption declines over time as initial capital depreciates away.

[18] We also verify this 11% assumption by using the perpetual inventory method to estimate the depreciation rate based on the total energy savings and incremental energy savings each year. The perpetual inventory formula tells us that total energy savings in year t equals incremental energy savings in year t + (1 - depreciation rate)*(total energy savings in year t-1). To determine the depreciation rate, we regress (total - incremental energy savings) in period t on total energy savings in period (t-1) to estimate (1 - the depreciation rate). This regression reveals a depreciation rate of 11%.

The perpetual inventory method thus yields a levelized annual cost of energy efficiency DSM programs in 2000 of $1.78 billion (2002 dollars). The cost-effectiveness estimate is $2.89 billion (2002 dollars) per quad of primary energy saved or 3.4 cents per kWh end-use consumption if all savings were in the form of electricity.[19] This estimate includes only costs to utilities and does not include any out-of-pocket expenditures by consumers or other costs borne by consumers such as diminished service quality (e.g., less water in the shower due to low-flow shower heads) or transaction costs associated with participation in the DSM program. It also does not include expenditures or energy savings resulting from load management programs. Load management programs tend to result in few energy savings, but comprise approximately 35% of total utility DSM costs circa 2000. Including load management programs in the estimate raises the cost to $4.68 billion (2002 dollars) per quad or 5.5 cents per kWh if all savings were in the form of electricity.

Our rough cost-effectiveness estimate for energy efficiency utility DSM in 2000 falls at the low end of the range of estimates of negawatt costs reported in the literature in the mid 1990s. These estimates typically range from around $3 billion (2002 dollars) per quad for energy efficiency utility costs (from EIA, reported in Raynold and Cowart (2000)) to $19.64 billion per quad when free riders are explicitly accounted for (Loughran and Kulick (2004)). For comparison, our rough estimate of $2.89 billion per quad is close to the EIA estimate.[20] If free ridership is an important consideration, then $2.89 billion per quad underestimates cost-effectiveness. Joskow and Marron (1992) propose doubling the more-common EIA estimate to deal with the understating of costs and overstating of energy savings that they believe plague most estimates of negawatt costs.[21]

The carbon emissions savings from utility DSM programs of just over 10.0 million metric tons of carbon equivalent, or approximately 0.6% of total U.S. emissions, follow directly from combining the estimates of energy savings with the average carbon emissions rate for the

[19] Using a 4% discount rate instead of 7% yields slightly lower estimates of $2.4 billion per quad or 2.8 cents per kWh.

[20] Note we still do not account for free riders (or spillovers) in this estimate and only utility costs are considered.

[21] $6 billion per quad would translate to 7.0 cents per kWh (using a conversion factor of 1.166 cents per kWh/billion dollars per quad) assuming all of the utility DSM energy savings came in the form of electricity (again, using a heat rate of 11,660 Btu per kWh).

electricity sector in 2000 of 16.3 million metric tons of carbon per quad of primary energy (EIA 2003b).

As discussed in section 3.1.3, all of these estimates are subject to a substantial amount of error due to a host of issues ranging from inconsistencies across utilities in how to measure energy savings to adjustment of these estimates for free riders or spillovers. As with appliance standards, estimates based on engineering models typically don't capture changes in consumer behavior, and, as a result, tend to overstate energy savings. Free riding is also a problem as programs may claim benefits for investments that energy users would have made without the program. Correspondingly, spillovers may be a problem if programs fail to claim benefits from non-participants for investments they would not have been made in the absence of the program.

Whether DSM programs, in the aggregate, provide positive net benefits or not is difficult to determine. The average electricity price in 2002, a proxy for the average value of energy saved due to DSM, was $6.3 billion per quad (in 2002 dollars). This number is above our estimate and above many of the DSM cost-effectiveness estimates in the literature. However, many of the estimates of costs included in the literature, including the EIA data our estimate is derived from, are based on utility costs only, and accounting for costs to consumers would likely further extend the range upward. Similarly, a downward adjustment in energy savings to account for free-rider or take-back effects would also extend the cost-effectiveness range upward. On the other hand, spillover or free-driver effects could extend the cost-effectiveness range downward. In addition, pollution reductions are not accounted for, and these reductions should be part of the value of the social benefits of DSM.

Finally, there is considerable heterogeneity within the class of utility DSM programs. The costs reported here combine both high- and low-cost DSM programs and thus DSM programs with lower costs and larger positive net benefits than our average do exist. For example, "America's Best: Profiles of America's Leading Energy Efficiency Programs" documents the cost-effectiveness of some recent successful programs (York and Kushler 2003). In practice, an economically sound strategy would emphasize those specific DSM activities with the highest cost-effectiveness and eliminate those activities that are bringing down the average cost-effectiveness of DSM.

6.3 Information and Voluntary Programs

Obtaining reliable estimates of the energy savings from information and voluntary programs is even more challenging than for appliance standards or utility DSM. All of the available estimates come from the agencies that administer these programs, and information on the methods and assumptions used to generate most of these estimates is not available to us. In addition, some voluntary programs tend to overlap substantially with other programs such as utility DSM, which makes estimating the incremental savings for a particular program even more challenging.

Taking the numbers reported in the literature as given, we find that annual savings from those voluntary and informational programs for which we have estimates total as much as 2.27 quads per year. The largest components of these savings are associated with EPA's Energy Star program, with associated activities saving an estimated 0.9 quads per year in 2001.[22] Annual costs to the federal government of this program are roughly $50 million per year and no estimates of costs to firms and consumers are available. We estimate the associated carbon emissions reductions to be about 13.8 million metric tons of carbon.[23]

Following Energy Star, the next largest components of these estimated savings are from the 1605b voluntary registration of emissions reductions and the DOE Climate Challenge programs. According to DOE estimates, energy efficiency nonutility DSM activities registered under these programs save as much as 0.411 and 0.814 quads per year, respectively (McArdle 2003). The 1605b program does not make any attempt to distinguish those emissions reductions that would have occurred independently of the programs. Thus, the reductions actually induced by the program could range from zero (no induced reductions) to the upper bound (all induced reductions), with the true estimate not likely to be at either extreme.

The remaining savings estimates we have come from the Weatherization Assistance Program (WAP), the Industrial Assessment Centers (IAC) program, and DOE's Rebuild America program. Annual energy savings from the WAP program are estimated at 15 million

[22] This number comes from converting EPA's estimate of 80 billion kWh of energy saved in 2001 to quads, using an average annual heat rate of 11,660 Btu per kWh.

[23] This estimate comes from multiplying the energy saved estimate times the average carbon emissions rate for electricity of 16.3 million metric tons per quad of primary energy.

barrels of oil equivalent per year, which translates to 0.087 quads saved and an associated reduction of roughly 1.3 million metric tons of carbon.[24] In 2000, administering WAP cost $141 million (2002 dollars), with similar figures for other recent years. The IAC program has yielded approximately 0.02 quads of energy savings per year over the last 25 years, with associated carbon emissions reductions based on 2000 emissions rates for industrial energy users of 268,000 metric tons (DOE 2003c). The administrative cost of the IAC program is currently approximately $7 million per year (2002 dollars) (Anderson and Newell 2004). DOE estimates that its Rebuild America program saved 0.009 quads of energy in 2002 and estimates associated carbon emissions reductions of 0.21 million metric tons of carbon. Cost estimates are not available for the Rebuild America program.

6.4 Government Energy Use

Ex post estimates of reductions in government energy use are only available for the Federal Energy Management Program. Estimates suggest that government energy use has declined by roughly 0.067 quads per year, with associated emissions savings of just under 1 million metric tons of carbon. It is not clear to what extent these savings are the result of the program and would not have occurred otherwise.[25] It is unlikely that FEMP has saved no energy, but we have no further information on which to base a range.

6.5 The Big Picture

As Table 9 shows, the effectiveness and cost-effectiveness picture for energy conservation programs is like a puzzle with many missing pieces. Taking the estimates within this literature as given, these studies collectively suggest that programs for which ex post quantitative estimates of energy savings exist are likely to have collectively saved up to 4.1 quads of electricity annually. These estimates typically reflect the *cumulative* effect of programs (e.g., *all* appliance efficiency standards, past and present) on annual energy consumption. This

[24] Carbon emissions reductions are calculated using the average residential carbon emissions rate in 2000 from the Annual Energy Review (EIA 2003b).

[25] The estimate is based on a reduction in government buildings energy use between 1985 and 2001, some of which may have occurred independent of the program, as there has been a significant change in government energy use over that time (e.g., base closings)

total energy savings represents about 6% of annual nontransportation energy consumption, which has hovered around 70 quads in recent years. Most of these energy savings come from reduced energy use associated with residential and commercial buildings (and not from more efficient industrial processes), so another relevant basis of comparison is total energy use in buildings, which accounts for approximately 37.1 quads (or 53%) of the 70 quads of nontransportation consumption. On this basis, the program saved up to 12% of residential/commercial consumption.

Estimates suggest roughly 1.2 quads of the 4.0 quad maximum annual total energy savings, or roughly 30%, is attributable to federal appliance standards and 0.6 quads (or 15%) to DSM programs. Energy Star, Climate Challenge, and 1605b programs are likely to contribute no more than 0.9, 0.8, and 0.4 quads per year, respectively. Estimates of small amounts of energy savings from the Industrial Assessment Center program and the Federal Energy Management program (less than 0.1 quads each), and the DOE Rebuild America program and the Weatherization Assistance Program (0.009 and 0.003 quads, respectively), constitute the remainder of the roughly 4 quad maximum total.

Differing viewpoints in the literature suggest that this aggregate estimate could be either too low or too high. Our range does not fully account for many of these subtle factors, but the estimate is likely to be on the high side, as some of the included programs contain activities that would likely have occurred in the absence of the programs. On the one hand, the 4 quad maximum total excludes spillovers and estimates of energy savings associated with a number of smaller-scale information programs and with past tax incentive programs, although the latter is likely to be small and no federal tax incentives for conservation have been in existence for over a decade. On the other hand, many of the estimates that make up this total are taken directly from studies that have been criticized for attributing too much energy savings to particular programs due to free-rider effects and the difficulty of accurately representing the no-policy baseline, among other factors.

The aggregate costs and cost-effectiveness of these programs are much more difficult to summarize than the energy savings due to incomplete information and inconsistencies in the way costs are measured across programs and studies. For example, studies of the costs of appliance standards include the costs to consumers of more expensive appliances as well as the costs to the government of administering the standards, while the aggregate data on DSM program costs

collected by EIA includes only the costs to utilities of running the program. For most of the other programs, either no cost information is available or the available data are limited to the administrative costs born by the government. These discrepancies make it extremely difficult to calculate and compare cost-effectiveness across energy-efficiency programs.

In fact, cost estimates are only available for appliance standards and utility DSM, limiting estimates of cost-effectiveness to these two programs. As defined for the purposes of this study, cost-effectiveness is the cost of obtaining energy savings divided by the energy savings. This estimate is analogous to "negawatt cost" estimates, only using quads instead of kWh to capture *all types* of energy savings (not just electricity savings).[26] The estimates of cost-effectiveness are $3.3 billion per quad and $2.9 billion per quad for appliance standards and utility DSM respectively. The price of energy saved varies over time, but using 2000 as a benchmark, the price of electricity is $6.3 billion per quad. This suggests that as a group, appliance standards are likely to provide positive net benefits, and if non-utility costs are low, the same can be said for utility DSM.

These findings must be tempered by a few additional considerations, even above the obvious environmental benefits, which are the subject of the next section. First, if the demand for electricity falls in response to energy efficiency policy, the price of electricity may also fall given that the electricity supply curve is upward sloping. As a result, the electricity price may have been higher in the absence of policy. Taking this into account, we estimate the counterfactual electricity price without energy efficiency policy may have been 3% greater, or $6.5 billion per quad.[27] This consideration would increase the relevant energy price to compare the cost-effectiveness estimates to from the current price of $6.3 billion per quad approximately to the average of the current and counterfactual, or $6.4 billion per quad, a 1.5% increase.[28] The average is an approximation to a simultaneous drop in energy price with each increment of energy savings.

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[26] Multiply dollars per quad by 1.14 to convert to dollars per kWh.

[27] Using EIA (2004) to infer the NEMS price elasticity of energy supply (0.517), and our estimates of 4.1 quads saved from 70 quads of nontransportation energy use in 2000.

[28] A price decline would also result in a transfer from producers to consumers on inframarginal demand. This transfer would result in a gain to consumer surplus, but a loss to producer surplus and would therefore not typically be included in the welfare effects for the purposes of cost-effectiveness or cost-benefit analysis.

A further consideration is whether the energy saved should be valued at the *average* price of $6.3 billion per quad or at the *marginal* cost of electricity production (assuming all of the energy saved under the programs reviewed here is from electricity production). The electricity generation marginal cost curve is typically upward sloping, with the least costly generation done first, followed by increasingly costly generation. Energy conservation programs typically displace generation by the most expensive generators and because of the upward sloping marginal cost of electricity supply, the variable costs associated with that displaced generation will tend to be above the average variable cost of electricity supply. On the other hand, much of the total cost of delivering electricity from the generators to consumers is in the form of fixed costs that do not change with the quantity of electricity generated (e.g., the costs of transmission and distribution capacity). These costs should not be included in the short-run marginal cost. In the long run, however, the installation of additional transmission and distribution capacity may be delayed or even avoided by a decrease in electricity demand.

Unfortunately, a full accounting of the most appropriate measure of marginal energy cost is beyond the scope of the present study, and appropriate measures are not readily available. We therefore rely on the average price. To the extent that marginal generation costs exceed average variable generation costs, average price measures will be too low. To the extent that prices include fixed components of cost associated with delivering electricity that do not vary with electricity production, they are too high. On average, the capital costs of electricity distribution make up about 20% of the total electricity cost. Combined, the electricity transmission and distribution costs (including operations, maintenance, and capital costs) make up 38% of the total electricity cost (Martin 2004). Thus, if all of these costs are considered fixed costs that do not change with the quantity of electricity supplied, and if the marginal generation cost equals average cost, then the relevant price to which cost-effectiveness estimates should be compared should be reduced by 20-38%. Due to the speculative nature of these assumptions, it is not reasonable to adjust the bottom-line cost of electricity we compare the cost-effectiveness estimates to, but future study into this issue is warranted.

The studies reviewed here suggest that aggregate carbon emissions reductions associated with this set of conservation programs are likely to be at most 3.5% of total annual U.S. carbon emissions. Again, these estimates are subject to potentially large errors for all of the same reasons listed above for the difficulties with measuring energy savings, but they suggest that the

reductions are roughly equivalent to the percentage reductions that might arise with about a $35 (in 2002 dollars) per metric ton tax on carbon emissions (Weyant and Hill 1999).

6.6 Environmental Benefits

To quantify the ancillary environmental benefits associated with energy efficiency programs, we perform some simple calculations for each of the major pollutants that result from electricity production. Our goal is to roughly approximate the additional benefits per quad from reducing environmental externalities through reduced electricity use. There are likely to be savings in other forms of energy besides electricity—such as reduced home heating oil use—but to simplify this exercise, we assume that all savings are in the form of electricity. To be comparable with Table 9, we use estimates as proximate as possible to 2000 and assume recent policies are in place, providing a sense of what the environmental benefits would be for near-term energy efficiency policies.

We report environmental benefits in dollars per quad and as a percent of energy savings benefits per quad under the assumption that these energy savings benefits are equal to the 2000 national average price of electricity of $6.34 billion per quad (in 2002 dollars). The percentage measure can be thought of as the environmental "bonus" associated with a reduction in energy use. We address each of the pollutants separately: CO_2, NO_X, SO_2, PM-10, and mercury. No reliable environmental/health benefits in dollars per ton reduced (i.e., damages per ton) exist in the literature for mercury, so mercury is excluded from the final sum. This final sum amounts to an increase in benefits of roughly 10% due to reduced emissions of the other pollutants (Table 11). The sources of the data used to create Table 11 are summarized in Table 12.

To calculate the benefits due to reduced emissions of CO_2, we use an emissions factor of 14,368,862 metric tons of carbon per quad from the EPA E-grid database (EPA 2004a) and the mean value of environmental damages from CO_2 of $30 per metric ton of carbon based on studies surveyed by Working Group III of the Second Assessment Report (SAR) of the Intergovernmental Panel on Climate Change (IPCC) (Pearce et al. 1995). The results of this survey were reaffirmed in the Third Assessment Report of the IPCC (2001), and the two additional studies by Plambeck and Hope (1996), and Tol (1999) were added. The estimates of incremental damages of carbon dioxide emissions from each of these studies are compiled in Table 13. Multiplying the emissions factor by the averted damages in dollars per ton reduced

yields $0.431 billion per quad of energy reduced. This is 7% of the 2000 electricity price of $6.3 billion per quad.

Calculating the benefits from reduced emissions of NO_X due to energy efficiency programs is less straightforward because of the caps on NO_X emissions in certain parts of the country. Specifically, there is a cap on NO_X emissions in approximately 20 eastern states subject to EPA's NO_X SIP Call during the summer months and in Southern California under the Regional Clean Air Incentives Market (RECLAIM) program throughout the year. Under these caps, the allowances freed up by reductions in emissions from energy efficiency policies would be sold on the allowance market, allowing another facility to emit more NO_X and resulting in no net reductions in NO_X emissions. Under a cap, reductions in pollution due to energy efficiency policies will nonetheless serve to reduce the costs of emissions control to attain that cap.

At present, the NO_X SIP Call grants approximately 544,000 allowances throughout the Northeast, each allowance representing one short ton of NO_X (EPA 1998). In 2000, the RECLAIM program granted 16,970 allowances, with each allowance again representing one short ton of NO_X (Coy et al. 2001). Thus, we compute the percentage of NO_X under a cap as the total capped metric tons of NO_X divided by the appropriate estimate of nationwide emissions of NO_X. Nationwide emissions of NO_X in 2000 were 5,117,967 metric tons (EPA 2004a). After the SIP Call NO_X cap comes into full effect, emissions will be reduced to about two-thirds of their previous levels (Burtraw et al. 2001), so, for an appropriate comparison, we assume nationwide NO_X emissions of 4,788,869 metric tons. We find that 10.63% of nationwide NO_X emissions will be subject to a cap and thus not affected by energy-efficiency programs.

When emissions caps are in place, energy conservation programs can help to reduce the cost to industry of complying with the aggregate emissions cap. For purposes of simplification, we assume that the reductions in NO_X emissions from energy efficiency policies will have a negligible effect on the price of allowances, and thus the emissions control cost savings per ton for the emissions covered by the cap will be roughly equal to the allowance price. Since 2000, the allowance price has hovered around $700 (EPA 2004c), so we use $700 per metric ton to approximately capture the cost savings from energy efficiency policy-induced NO_X emissions reductions.

The damages per ton of NO_X emissions are estimated at $1,157 per metric ton (Banzhaf, Burtraw, and Palmer 2002), and this estimate is applied to the 89.3% of emissions that are not

capped. The weighted average of control cost savings and emissions damages per metric ton of NO_X emissions is multiplied by the emissions factor of 115,150 metric tons of NO_X per quad from the EPA E-grid database to estimate the additional benefit from energy efficiency policies of $0.128 billion per quad. This translates to an environmental bonus associated with NO_X emissions reductions of 2.01% of the 2000 electricity price.

SO_2 emissions from the electricity sector are under a nationwide cap, simplifying the calculations. The emissions factor for SO_2 is estimated to be 234,968 metric tons per quad (EPA 2004a). Just as in the case of NO_X, we use the SO_2 allowance price to roughly estimate the cost savings per ton for SO_2 emissions covered under the cap (i.e., all of them). The mean allowance price in 2000, averaged over the different brokerages, equates to $163.4 per metric ton (in 2002 dollars) (EPA 2004b). The damages from emissions of SO_2 are estimated to be $3,857 per metric ton (Banzhaf, Burtraw, and Palmer 2002), but under the cap, no net nationwide emissions reductions would occur from energy efficiency policies.

The SO_2 cost savings estimate is multiplied by the emissions factor, with the resulting $0.038 billion per quad in additional benefits from SO_2. Thus, there is a 0.61% additional bonus from SO_2 that is not captured by the energy savings alone, again based on the 2000 electricity price of $6.34 billion per quad.

For PM-10, the emissions factor is based on the estimate of 762,584 metric tons of PM-10 in 2000 (EPA 2004a), and the 38,181 quads of electricity produced in 2000 (EIA 2003b). The resulting emissions factor for PM-10 is 19,973 tons per quad. There is no cap on PM-10 emissions and current regulations on PM-10 would not change the emissions reductions from energy efficiency policies. Banzhaf et al. (1996) estimate damages from PM-10 in Minnesota under a variety of conditions ranging from $530 to $6,054 per short ton emitted, with a likely estimate that can be applied nationwide of $1,873 per short ton ($2,064 per metric ton). The benefits from reductions in PM-10 equal $0.041 billion per quad. Again, using the 2000 electricity price of $6.34 billion per quad, there is a 0.65% additional benefit from reducing PM-10 emissions. Note that PM-2.5 is included in the estimates we use for PM-10, consistent with the literature. We were also careful to use damage estimates that differentiate PM-10 from the secondary particulates that are derived from emissions of NO_X and SO_2 to avoid double counting, as these damages are already included in the benefits of NO_X and SO_2 reduction. This

results in a more accurate, but lower estimate of PM-10 damages than studies including secondary particulates derived from NO_X and SO_2.

The benefits from the reduction in mercury emissions cannot be as easily estimated, given the lack of available estimates of the damages from mercury emissions. Instead, we solve for what the damages from mercury emissions would have to be for mercury benefits to equal one percent of the energy savings benefit. The emissions factor for mercury is estimated to be 13.6 metric tons per quad (EPA 2004a). For a one percent additional benefit, there must be an additional benefit of $0.061 billion per quad, or damages from mercury amounting to $4,450,000 per metric ton. One of the few studies that ventured to estimate the health effects of mercury emissions, Rowe et al. (1995) obtained a high estimate of $35,000 (1995 dollars) per quad ($41,348 per quad in 2002 dollars). This approximate estimate, while far from definitive, suggests that the benefits from reduced mercury emissions are likely to be much less than one percent of energy savings benefits.

Although more uncertain than the energy reductions from which they result, the four pollutants for which we have estimates may provide a total additional benefit of just over 10% to the value of energy savings from energy efficiency policies. A cursory sensitivity analysis with higher values of $/ton environmental benefits indicates that even environmental benefits values that are double our estimates for NO_X, SO_2, and PM-10 would not change the overall result of 10% by more than a few percentage points.

7. Conclusions and Implications for Future Research

Greater energy efficiency of the economy is one of the primary avenues for reducing carbon emissions associated with the combustion of fossil fuels, along with switching to low- and no-carbon fuels and carbon sequestration. Improved energy efficiency may also serve "energy security" goals by lessening the effect of fuel supply disruptions and helping to re-shape electricity load profiles to avoid peak-use problems. Several key questions therefore immediately arise regarding the role of policies supporting energy efficiency within a portfolio of prospective energy and climate policies. First, what types of energy efficiency policies have been employed in the United States and how well has each of these policies worked in terms of saving energy? Second, how much have these programs cost the public and private sector and what has been their cost-effectiveness? Finally, what are the prospects for future energy savings and carbon

reductions from policies directly promoting energy efficiency? In other words, how large a role might we expect energy efficiency improvements to play in meeting carbon mitigation goals?

Providing answers to these seemingly straightforward questions quickly runs up against data problems, limits to information, and deep-seated methodological challenges and debates about how to properly measure and predict the costs, benefits, and effectiveness of past and prospective policy. Some analysts maintain, for example, that a substantial amount of carbon emissions reductions could come from greater energy efficiency at very low, zero, or even negative cost to the U.S. economy (Brown et al. 2001; Interlaboratory Working Group 2000). Many economists are much more skeptical. One can get some perspective on this debate by analyzing the effectiveness and cost-effectiveness of current and past government programs to bring about greater energy conservation.

Our review of existing estimates of the effects of energy conservation programs suggests that, taken together, the conservation programs we reviewed are likely to have saved up to 4 quads of energy per year and reduce annual carbon emissions by up to 63 million metric tons, or about 4% of 2000 emissions. According to the estimates in the literature, the lion's share of these energy savings and associated emissions reductions come from appliance standards and utility DSM programs; EPA's Energy Star Program, 1605b, and Climate Challenge also may provide large benefits. Even rough measures of cost-effectiveness are only available for appliance standards and utility DSM, and these paint a mixed picture about how the average costs of achieving energy savings compare to the average value of the energy cost savings they produce. Appliance standards as a group appear to be cost-effective and typically yield positive net benefits from energy savings alone and additional benefits from ancillary reductions in air pollution. DSM programs also appear cost-effective, although it is difficult to determine whether unaccounted costs to consumers are high, in which case, these programs would be less cost-effective. However, DSM programs also produce ancillary reductions in air pollution that would augment reported benefits. In addition, there is considerable heterogeneity in the cost-effectiveness of DSM programs and thus there are lower-cost DSM programs with larger positive net benefits. This suggests there may be benefits to emphasizing DSM activities with the highest cost-effectiveness and eliminating those activities that are less cost-effective.

Including the additional environmental benefits from reducing emissions of CO_2, NO_X, SO_2, and PM-10 could add a bonus of approximately 10% to the value of energy savings from

energy efficiency programs. The majority (7%) of these benefits are derived from CO_2, with fewer benefits from NO_X (2%), and even fewer from SO_2 and PM-10 (0.5% each). The inclusion of environmental benefits strengthens the case for both appliance standards and utility DSM, although not by a large percentage.

The studies reviewed here raise several issues concerning past efforts to measure both the effectiveness and cost-effectiveness of conservation programs. For almost all of the energy efficiency programs reviewed, estimates of effectiveness and cost-effectiveness are controversial. Measuring the effectiveness or total energy savings from a conservation initiative or program can be problematic.

Questions arise about what energy consumption would have been in the absence of the program (the baseline definition issue) and whether or not some of the energy savings attributed to the program would have happened anyway (the free-riding issue). Estimates of energy savings from particular efficiency enhancing investments also often fail to account for the fact that energy demand may rise with the investment (i.e., the "rebound" effect), particularly if it lowers the marginal cost to consumers of energy services such as heating, lighting, or hot water. The discount rate assumed for computing the present value of energy savings also can have a large effect on the estimated benefits of these programs. Effectiveness could also be mismeasured and double-counted when the same energy savings are attributed to multiple government programs.

The main question that arises when measuring program cost-effectiveness is whether or not all of the salient costs (costs to business, costs to consumers, including consumer surplus losses due to quality changes, and costs to the government) and energy savings (including any spillovers) are being properly accounted for. Estimates of costs are also plagued by many of the same sources of error that affect estimates of energy savings, including potential misspecification of baselines, free-rider effects, omission of relevant costs, double-counting across programs, and the use of inappropriate discount rates. The relevant "benefit" to compare our cost-effectiveness estimates to is also difficult to ascertain, with data readily available only on the average cost of electricity, rather than the marginal cost of electricity. All of these potential sources of error suggest that considerable care must be taken in interpreting existing estimates of the costs, energy savings, and cost-effectiveness, from energy efficiency programs.

Our survey of the literature reveals a striking lack of independent academic ex post analyses of conservation programs. Several studies have presented general critiques of methods

used to estimate energy savings and costs of appliance standards and of DSM programs, but there are very few independent academic studies that take a detailed look at the effectiveness and the costs of specific programs after they have been implemented. Such an analysis is key to understanding the robustness of the effectiveness and cost-effectiveness estimates reported here to changes in assumptions about discount rates and other assumptions regarding the growth in future energy demand. Detailed analysis would be particularly important for classes of programs, such as appliance standards, that policymakers may plan to use more widely in the future.

Several recent policy initiatives and proposals suggest that efforts to promote energy conservation will continue in the future. The conference draft of the energy efficiency part of the 2003 Energy Bill calls for further reductions in energy intensity at federal buildings, cumulating to 20% below 2001 levels by 2020. The bill also provides tax credits for efficiency investments, expands energy efficiency standards to new products, and provides federal funding for state-run rebate programs to encourage the replacement of existing inefficient appliances with Energy Star appliances and for energy efficiency enhancements in public housing, among other proposals.

Recent legislation (S. 366) sponsored by Senator Jeffords (I-VT)[29] to cap emissions of multiple pollutants from electricity generators uses a cap and trade approach and calls for allocating 20% of the emissions allowances to new renewable generation, new combined heat and power capacity, and energy conservation initiatives. This approach is analogous in some ways to the Conservation and Renewable Energy Reserve (CRER) feature of Title IV, although the incentives created by set-aside allowances in S. 366 would be much stronger than the CRER set-asides, due to both a greater number and value of the allowances.

The continued use of energy efficiency policies over more than two decades, and the prospect of expanded and new policies on the horizon suggest that this approach to achieving energy and carbon reductions will have a lasting presence. While existing estimates indicate that the current impact of these policies is modest, it does appear that well-designed future programs have the potential to reduce energy and emissions, although the magnitude of potential reductions and the cost of achieving those reductions are open questions.

[29] For more information, see www.rff.org/multipollutant (accessed 11/3/03).

Tables

Table 1. Overview of Demand-Side Energy Efficiency Policies/Programs

Program	Brief Description
Energy Efficiency Standards	
Federal Appliance/Equipment Standards	First promulgated by the 1987 National Appliance Energy Conservation Act. Updated several times, most notably by the 1992 Energy Policy Act. Currently covers: refrigerators, freezers, air conditioners, furnaces, water heaters, space heaters, clothes washers/dryers, dishwashers, ranges/ovens, pool heaters, certain lamps, ballasts, electric motors, and commercial heating/cooling equipment.
State Appliance/Equipment Standards	Provided the impetus for federal standards, but today largely usurped by federal standards. Several state appliance standards do exist in the following markets: distribution transformers, traffic lights, commercial refrigerators/freezers, exit signs, plumbing fittings/fixtures, space heaters, and demand control ventilation devices.
Building Codes	Many state and local building codes have energy efficiency clauses mandating construction techniques or energy efficient materials.
Professional Codes	Primarily the ISO 14001, which is a series of international standards that have been developed for incorporating environmental concerns into corporate operations and product standards. Companies can be registered to ISO 14001 through the implementation of a company-wide environmental management system in accordance with the specified standards, which include energy efficiency concerns in product life-cycle assessment, environmental performance evaluation, and environmental labeling.
Corporate Average Fuel Economy (CAFE) Standards	The 1975 Energy Policy and Conservation Act required all passenger car and light truck manufacturers to meet the fleet-wide CAFE standards. These standards have since been updated several times, most recently in 1995 to 27.5 miles per gallon for cars and 20.7 miles per gallon for light trucks.
Financial Incentives for Energy Efficient Investment	
Financial Incentives for Consumer Purchases	Rebates and low-interest loans provided by utilities to consumers who purchase energy efficient appliances or equipment, as part of utility DSM programs. Golden Carrot programs are designed to transform the market for a particular good, generally through utility-provided financial incentives to manufacturers.
Electricity Load Management	Provides a financial incentive to electricity consumers in exchange for a reduction in electricity demand. This can be done through contracts between the utility and the consumer as in direct load control, interruptible load programs, voluntary demand response programs, and demand-side bidding programs.
Income Tax Deductions	Federal tax deductions for individuals who purchase clean fuel or electric vehicles starting in 2002 at $2,000 and phased out by 2006. From 1978 to 1986, a $2,000 residential energy conservation credit also existed.
Emissions Allowances Allocated to Demand-Side Investments	Under Title IV of the 1990 Clean Air Act, 300,000 SO_2 allowances were set aside into a reserve fund to be awarded to utilities that employed renewable or energy efficiency measures. Only 47,493 were actually awarded. Pending legislation proposes to include a similar reserve.

Table 1. Overview of Demand-Side Energy Efficiency Policies/Programs

Program	Brief Description
Information and Voluntary Programs	
Voluntary CO_2 Reductions	Voluntarily reported and registered under Section 1605b of the 1992 Energy Policy Act.
DOE Climate Challenge	A voluntary public-private partnership between electric utilities and DOE, designed for utilities to set goals for emissions reductions and report periodically to DOE on their progress.
Energy Star Programs	Provides Energy Star labels to energy efficient products, equipment and buildings. The program also has partnerships with public and private organizations to provide technical information and advice on choosing the most energy efficient practices. The EPA Climate Wise program is an example of a partnership program under the auspices of Energy Star.
DOE Energy Efficient Buildings Programs	Homebuilders are provided with technical assistance to help them build more energy efficient homes in the DOE Building America program. DOE Rebuild America creates public-private partnerships at the community level to find and implement opportunities for energy savings improvements.
Partnership for Advanced Technology in Housing (PATH)	PATH is a Department of Housing and Urban Development coordinated public-private initiative dedicated to accelerating the development and use of new technologies in the housing sector, including more energy efficient technologies.
Industrial Energy Audits	Provides free comprehensive industrial assessments, including energy audits, to small and medium-sized manufacturers through the Industrial Assessment Center (IAC) program and for large manufacturers through the Plant-wide Assessment (PWA) program.
State Industrial Energy Efficiency Programs	These programs vary, but are typically energy audit and informational programs. There are approximately 300 programs.
Product Labeling Requirement (EnergyGuide)	In 1980 the FTC's Appliance Labeling Rule became effective, requiring "EnergyGuide" labels on most new energy intensive consumer appliances to show the relative energy use compared to other models of the same type of appliance.
Weatherization Assistance Programs	DOE Weatherization Assistance program and Low-Income Home Energy Assistance Program (LIHEAP) both provide technical assistance and some financial assistance to end-users, particularly low-income end-users, to improve home energy efficiency.
Management of Government Energy Use	
Federal Energy Management Program (FEMP)	Provides technical assistance to government facilities to promote the use of energy efficient equipment and to better manage government energy use.
Federal Procurement	Among other regulations, the Federal Acquisition Regulations 1997 requires the federal government to purchase Energy Star equipment and build Energy Star certified homes. The 1992 Energy Policy Act also gave DOE the authority to develop a government fleet acquisition program to encourage clean fuel and energy efficient vehicles.
Air Traffic Management	EPA and FAA are working together on the Communication, Navigation, Surveillance/Air Traffic Management (CNS/ATM) system to better manage flight patterns so as to reduce aviation energy use and emissions. Other improved operating practices are also being examined.

Table 2. Effective Dates of Appliance Efficiency Standards, 1988–2007

Equipment type	88	90	92	93	94	95	00	01	04	05	06	07	10
Clothes dryers	X				X								
Clothes washers	X				X				X			X	
Dishwashers	X				X								
Refrigerators and freezers		X		X				X					
Kitchen ranges and ovens		X											
Room air conditioners		X					X						
Direct heating equipment		X											
Fluorescent lamp ballasts		X											
Water heaters		X							X				
Pool heaters		X											
Central a.c. and heat pumps			X								X		
Furnaces—central and small			X										
Furnaces—mobile home		X											
Boilers			X										
Fluorescent lamps—8 ft					X					X			X
Fluorescent lamps—2, 4 ft						X				X			X

Source: EIA (1999) and Meyers (2003)

Table 3. Comparison Between California and the Federal Government for the Setting of Appliance Standards.

Year	California	Federal Government
1976	Adopted standards for refrigerators and A/Cs	
1977	Adopted standards for heating, water heating, and water use	
1978/79		Published test methods for consumer appliances
1980		Proposed standards for consumer appliances
1982		"No-standard" policy of Reagan administration
1983	Adopted standards for fluorescent lamp ballasts	
1984	Adopted tougher refrigerator and A/C standards	
1985	Adopted tougher heat pump standards	
1987		National Appliance Energy Conservation Act (NAECA)
1988		Amendments to NAECA for ballasts
1992		Energy Policy Act (EPAct)
1994	Received petition for more stringent ballast, water heater, and clothes washer standards	
1996		Temporary Congressional moratorium on standard development
1997		Adopted tougher refrigerator standards
2001		Tougher refrigerator standards take effect

Source: Martin (1997)

Table 4. EIA Estimates of Utility Demand-Side Management Spending, 1989–2001.

Year	DSM Spending (millions 2002 dollars)	Incremental Energy Savings (GWh)	Annual Energy Savings (GWh)
1989	$1,276	N/A	14,672
1990	$1,633	N/A	20,458
1991	$2,401	N/A	24,848
1992	$3,034	6,712	35,893
1993	$3,442	9,002	45,294
1994	$3,322	8,248	52,483
1995	$2,880	8,243	57,421
1996	$2,198	6,857	61,842
1997	$1,848	4,860	56,406
1998	$1,580	3,379	49,167
1999	$1,549	3,103	50,563
2000	$1,648	3,364	53,702
2001	$1,678	5,318	54,762

Note: One GWh is equivalent to one million kilowatt-hours.
Source: EIA (2003c) and EIA (2003b)

Table 5. Nadel and Kushler Estimates of Utility Demand-Side Management Spending, 1989–1998.

Year	DSM Spending (millions 2002 dollars)	Annual Energy Savings (GWh)
1989	$1,220	14,672
1990	$1,576	20,458
1991	$2,324	24,848
1992	$2,943	35,563
1993	$3,351	45,294
1994	$3,240	52,483
1995	$2,823	57,421
1996	$2,177	61,842
1997	$1,839	57,193
1998	$1,744	56,866

Source: Nadel and Kushler (2000)

Table 6. Selected Products in the Energy Star Labeling Program, 2003.

Product	Agency	Energy Savings Above 'Standard' New Products	Market Share of Qualifying Products in 2000
Computer (Home)	EPA	27%	95%
Computer (Work)	EPA	52%	95%
Monitor (Home)	EPA	27%	97%
Monitor (Work)	EPA	52%	99%
Copiers	EPA	42%	90%
Faxes	EPA	40%	99%
Televisions	EPA	24%	46%
VCRs	EPA	29%	94%
TV/VCRs	EPA	30%	76%
Audio	EPA	69%	31%
Central Air Conditioners	EPA	24%	20%
Furnaces (Gas)	EPA	15%	27%
Programmable Thermostats	EPA	20%	36%
Clothes Washers	DOE	38%	10%
Dishwashers	DOE	25%	20%
Refrigerators	DOE	10%	17%
Room Air Conditioners	DOE	10%	13%
Lighting Fixtures	EPA	66%	3-5%
Lighting Bulbs	DOE	66%	3%
Exit Signs	EPA	75%	75%
Windows	DOE	range	range

Source: EPA (2003a)

Table 7. Cumulative Savings Through 1999 from Energy Star Labeling Program.

Product	Start Year	Energy Savings (petajoules or millions GJ)	Energy Bill Savings, Undiscounted (millions 2002 dollars)	Carbon Emissions Avoided (MtC)
Computers/Monitors	1993	360	$2,757.7	6.6
Copiers	1995	26	$198.6	0.48
Faxes	1995	21	$165.5	0.39
Multifunction devices	1997	0.41	$3.0	0.0075
Scanners	1997	27	$198.6	0.50
Printers	1993	150	$1,103.0	2.8
Televisions	1998	6.3	$49.6	0.12
VCRs	1998	3.0	$24.3	0.055
TV/VCRs	1998	0.50	$4.0	0.0092
Audio	1999	1.9	$15.4	0.035
Central Air Conditioners	1995	0.83	$6.6	0.020
Furnaces (Gas or Oil)	1995	1.4	$9.7	0.015
Air-source heat pumps	1995	0.54	$4.3	0.010
Geothermal heat pumps	1995	0.14	$1.1	0.0026
Gas-fired heat pumps	1995	0.00036	$0.002	0.0000064
Boilers (gas or oil)	1995	0.069	$0.5	0.011
Programmable Thermostats	1995	39	$287	0.62
Clothes Washers	1996	31	$242.7	0.55
Dishwashers	1996	5.3	$42.0	0.091
Refrigerators	1996	21	$165.5	0.38
Room Air Conditioners	1996	7.3	$59.6	0.13
Lighting Fixtures	1997	14	$109.2	0.250
Exit Signs	1995	41	$297.8	0.75
New Homes	1995	0.8	$6.0	0.013

Source: Webber et al. (2000)

Table 8. DOE Weatherization Assistance Program Appropriations, 1977-2003.

Year	DOE Appropriations to WAP (millions 2002 dollars)
1977	$81.6
1978	$179.2
1979	$492.8
1980	$434.2
1981	$346.1
1982	$268.3
1983	$442.3
1984	$328.8
1985	$319.3
1986	$298.7
1987	$255.3
1988	$245.2
1989	$233.9
1990	$222.9
1991	$262.6
1992	$248.6
1993	$230.7
1994	$250.9
1995	$253.4
1996	$128.0
1997	$135.3
1998	$137.7
1999	$143.5
2000	$141.0
2001	$155.3
2002	$230.0
2003	$219.9

Source: WAP (2003)

Table 9. Summary of Estimates from Existing Studies of the Effects of Energy Efficiency Programs in 2000.

Program	Date	Energy Savings (quads)	Costs (billion $2002)	Cost-Effectiveness (billion $2002 per quad)[d]	Carbon Emissions Savings (MMtCE)
Appliance Standards	2000	1.20 [a]	$2.51 [a]	$3.28 [a]	17.75 [a]
Financial Incentives					
Utility DSM	2000	0.62	$1.78 [e]	$2.89 [e] (high $19.64)	10.02
Tax Incentives	-	-	-	-	-
Emissions Allowances	-	-	-	-	-
Information and Voluntary Programs					
1605b registry	2000	<0.41[c]	$0.0004	-	<6.08
DOE Climate Challenge	2000	<0.81	-	-	<12.04
Energy Star	2001	<0.93	$0.05 [b]	-	<13.80
DOE Rebuild America	2002	0.01	-	-	0.21
PATH	2000	-	$0.002 [b]	-	-
Industrial Assess. Centers (IAC)	~2000	0.02	$0.007 [b]	-	0.27
Energy Guide		-	-	-	-
Weatherization Assistance Program	2003	0.09	$0.14 [b]	-	1.35
LIHEAP	2002	-	$0.20 [b]	-	-
Government Energy Use					
Federal Energy Management Program	2002	<0.07	$0.025 [b]	-	<0.99
Federal Procurement	-	-	-	-	-
Air Traffic Management	-	-	-	-	-
Total		**<4.1**			**62.5**

[a] indicates that total costs and cost-effectiveness estimates are for residential appliance standards only while the energy and carbon savings estimate is for commercial *and* residential. Residential appliances yielded approximate 0.77 quads of energy savings in 2000.

[b] indicates that only direct government administrative costs are included.

[c] < indicates a likely upper bound of energy savings or emissions reductions.

[d] Billion dollars per quad can be roughly converted to cents/kWh by multiplying by 1.166, which assumes all of the savings come from electricity, using the average mix of generating facilities. We emphasize the use of quads because many of the programs cover nonelectricity reductions, which have a different heat rate than electricity.

[e] Indicates only utility costs are included.

Table 10. Sources of Estimates in Table 9

Program	Energy Savings	Costs	Carbon Emissions Savings
Appliance Standards	Geller et al. (2001) and McMahon (2004)	authors' calculations based on McMahon (2004)	authors' calculations based on EIA (2003b) and Geller et al. (2001)
Financial Incentives			
Utility DSM	authors' calculations based on EIA (2003b)	authors' calculations based on EIA (2003b)	authors' calculations based on EIA (2003b)
Tax Incentives	-	-	-
Emissions Allowances	-	-	-
Information and Voluntary Programs			
1605b registry	McArdle (2003)	GAO (1998)	McArdle (2003)
DOE Climate Challenge	McArdle (2003)	-	McArdle (2003)
Energy Star	EPA (2002)	Malloy (2003)	authors' calculations based on EIA (2003b) and EPA (2002)
DOE Rebuild America	DOE (2002)	-	DOE (2002)
PATH	-	NAS (2003)	-
Industrial Assess. Centers (IAC)	DOE (2003c)	Anderson and Newell (2004)	DOE (2003c)
Energy Guide	-	-	-
Weatherization Assistance Program	WAP (2003)	WAP (2003)	WAP (2003)
LIHEAP	-	LIHEAP (2003)	-
Government Energy Use			
Federal Energy Management Program	FEMP (2002)	FEMP (2002)	FEMP (2002)
Federal Procurement	-	-	-
Air Traffic Management	-	-	-

Table 11. Annual Environmental Benefits of Emissions Reduction (circa 2000).

Pollutant	Emission factor (ton/quad)	Cost savings under cap ($/ton)	% under cap	Environmental Benefits ($/ton)	% not capped	Additional benefit from reduction (billion $/quad)	% increased benefit or "bonus"
Carbon	14,368,862		0%	30	100%	0.431	6.80%
NO_X	115,150	700	10.6%	1,157	89.3%	0.128	2.01%
SO_2	234,968	163.4	100%	3,857	0%	0.038	0.61%
PM-10	19,973		0%	2,064	100%	0.041	0.65%
Total							10.08%
Mercury	13.6		0%	4,650,000*	100%	0.061	1.00%

Note: * indicates what the environmental benefits would have to be to result in a 1% increase in the energy savings benefits. All tons are metric tons; all $ figures are 2002 dollars. Environmental "bonus" is as a perecent of the 2000 average electricity price of $6.8 billion per quad.

Table 12. Sources of Estimates in Table 11

Pollutant	Emission factor (ton/quad)	Cost savings under cap ($/ton)	Environmental Benefits ($/ton)	% capped
Carbon	EPA (2004a)		See Table 13	
NO_X	EPA (2004a)	EPA (2004c)	Banzhaf et al. (2002)	authors' calculations
SO_2	EPA (2004a)	EPA (2004b)	Banzhaf et al. (2002)	
PM-10	EPA (2004a)		Banzhaf et al. (1996)	
Mercury	EPA (2004a)			

Table 13. Incremental Damages of Carbon Dioxide Emissions for 2001–2010.

Study	**Damages** (US$2003 per ton of carbon)
Nordhaus (1994b) (expected value from SAR Table 6.11)	24
Ayres and Walter (1991) (from SAR Table 6.11)	43
Cline (1993d) (Cline's preferred scenario)	72
Peck and Teisberg (1992) (from SAR Table 6.11)	17
Fankhuser (1994b) (from SAR Table 6.11)	30
Maddison (1994) (from SAR Table 6.11)	11
Plambeck and Hope (1996) (their preferred scenario)	28
Tol (1999) (see Table 4 of paper)	17
Median	**26**
Mean	**30**

Note: See IPCC Second Assessment Report (SAR), Working Group III, Chapter 6 (1995) and the IPCC Third Assessment Report, Working Group II, Chapter 19 (2001) for detailed references. Figures inflated to 2003 dollars using the GDP price index.

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