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ENERGY EFFICIENCY POLICIES: A Retrospective Examination

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■ **Abstract** We review literature on several types of energy efficiency policies: appliance standards, financial incentive programs, information and voluntary programs, and management of government energy use. For each, we provide a brief synopsis of the relevant programs, along with available existing estimates of energy savings, costs, and cost-effectiveness at a national level. The literature examining these estimates points to potential issues in determining the energy savings and costs, but recent evidence suggests that techniques for measuring both have improved. Taken together, the literature identifies up to four quads of energy savings annually from these programs—at least half of which is attributable to appliance standards and utility-based demand-side management, with possible additional energy savings from the U.S. Department of Energy's (DOE's) ENERGY STAR, Climate Challenge, and Section 1605b voluntary programs to reduce carbon dioxide (CO_2) emissions. Related reductions in CO_2 and criteria air pollutants may contribute an additional 10% to the value of energy savings above the price of energy itself.

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INTRODUCTION

Energy efficiency plays a critical role in the U.S. energy policy debate because future national energy needs can be met only by increasing energy supply or decreasing energy demand. The prospects of climate change, air pollution, and energy security all cast an undesirable shadow over an exclusive focus on increasing energy supply to meet growing demand; current U.S. greenhouse gas emissions are ~1580 million metric tons of carbon equivalent (MMTCE)/year and rising (1). Many energy efficiency advocates maintain that the vigorous use of policies that encourage consumers and manufacturers to use less energy could effectively manage national energy needs at very little or no cost.

By examining the past performance of many policies and programs that promote energy efficiency, we address some important questions related to how demand-side policies might fit into a comprehensive energy policy: Which policies and programs have been implemented in the past? What have they accomplished, and how do they compare? How much have the public and private sectors spent on them? Have the policies and programs been cost-effective?

In this descriptive survey of demand-side energy efficiency policies, we focus on the adoption of energy-efficient equipment and building practices rather than on energy research and development. Although the applicable programs and policies span quite a broad range, they tend to fall into four general categories: appliance standards, financial incentive programs (for energy-efficient investments), information and voluntary programs, and management of government energy use. We limit the study scope by omitting building codes, professional codes, and transportation polices (including Corporate Average Fuel Economy Standards).

In this chapter, we present a brief history and a literature review of the cost and effectiveness of each program category; an overall picture created from estimated energy savings, cost-effectiveness, and emissions reductions; and some general conclusions. We focus our review on national-level estimates to ensure comparability across programs. Additional details can be found in Gillingham et al. (2).

APPLIANCE STANDARDS

U.S. standards for the minimum energy efficiency of appliances began during energy crisis of the the mid-1970s, when high prices and increased environmental concerns drove many states to consider ways to cut growing energy demand (3). California passed legislation that paved the way for New York and other states, and manufacturers soon pushed for uniform federal standards.

Early efforts to set national standards were largely ineffective until a collaboration of manufacturers and energy efficiency advocates resulted in the 1987 National Appliance Energy Conservation Act (NAECA) (4). The NAECA established national standards for 15 categories of household appliances: refrigerators, freezers, clothes washers, clothes dryers, dishwashers, kitchen ranges, kitchen ovens, room air conditioners, direct heating equipment, water heaters, pool heaters, central air conditioners, central heat pumps, furnaces, and boilers. These initial standards have been updated several times, and standards were added for showerheads and fluorescent light ballasts in 1988. The next major energy efficiency legislation was the 1992 Energy Policy Act (5), which extended standards to induction motors, many kinds of lamps, and most types of commercial heating and cooling equipment.

Cost-Effectiveness Estimates

Many studies evaluate the effectiveness of appliance standards, in general or for particular appliances. Most studies are *ex ante*, performed for the U.S. Department of Energy (DOE) by researchers at Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, or the American Council for an Energy-Efficient Economy; DOE Technical Support Documents also contain an extensive amount of *ex ante* analysis. A few studies present *ex post* estimates.

Levine et al. (6) estimate the cumulative effectiveness of appliance standards from a combination of *ex post* and *ex ante* analyses. Estimated federal government expenditures for the appliance efficiency program are US$61(2002) million for 1979–1993; the estimated total net benefit of appliance standards for appliances sold in 1990–2015 is $56 billion—a net present cost of $39 billion for higher-priced appliances and a net present savings of $95 billion as a result of saved energy operating costs. (Note: Unless otherwise noted, all monetary values are in 2002 U.S. dollars, and all present values are discounted at 7%.) Estimated energy savings from appliance standards in 1994 alone are 0.1 quad, which represents almost $1.23 billion. Total national carbon dioxide (CO_2) emissions are estimated to decrease 1.5% to 2% by 2015 as a result of the standards.

In a widely cited *ex ante* study, Geller (7) estimates prospective total energy savings from appliance standards in 2000 as 1.23 quads. Geller et al. (8) later estimate energy savings as 1.2 quads in 2000 and cumulative net benefits of $196 billion through 2030.

In one of the few *ex post* analyses of appliance standards, McMahon et al. (9) provide retrospective estimates of energy savings, net benefits, and carbon reductions for 1990–1997. Because few appliance standards took effect before 1990, these cumulative estimates are roughly comparable with other cumulative estimates for 1987–1997. Estimated cumulative energy savings are 1.9 quads for 1990–1997, with a cumulative benefit from energy savings of \$17 billion and CO_2 emissions reduced by 29.5 MMTCE. The largest effects are seen in the final few years studied; 45% of the benefits and 46% of energy savings and emissions reductions occur in 1996 and 1997. McMahon et al. (9) attribute this finding to the increasing percentage of total appliances in use that meet the standards. Correspondingly, the study contains *ex ante* forecasts of future energy savings, net benefits, and emissions reductions from appliance standards that continue to increase greatly.

Ex post and *ex ante* analyses from Meyers et al. (10) estimate past costs to the government of implementing 1987–2000 appliance standards as \$200 million to \$250 million and the cumulative net benefit for those years as \$17.4 billion. This latter amount is added to some *ex ante* estimates to yield a cumulative net benefit of \$154 billion and CO_2 emissions reductions of 1216 MMTCE for 1987–2050.

Finally, J. McMahon (personal communication) provides the underlying time series of estimates used in Meyers et al. (10), including the year 2000 annual energy savings and aggregate cost to consumers and government of implementing residential appliance standards. Estimated residential annual energy savings are 0.59 quads of electricity and 0.19 quads of natural gas for 2000; with 2000 prices of \$6.3 billion/quad for electricity and \$5.6 billion/quad for natural gas, total energy savings are \$4.8 billion. The total estimated equipment cost to consumers is \$2.5 billion in 2000. This time series of energy savings and cost estimates form the basis for an estimate of cost-effectiveness of \$3.28/quad saved [for more details, see Gillingham et al. (2, pp. 56–58)].

Critiques and Responses

Several authors are more skeptical of these estimates of cost-effectiveness. Khazzoom (11) claims that energy efficiency improvements reduce the effective cost of energy services, thereby increasing demand and inducing less-than-proportional reductions in energy use. According to Khazzoom, this so-called *take-back effect* or *rebound effect* implies that mandated standards do not yield the energy savings or cost-effectiveness that *ex ante* estimates predict and that for some major end uses mandated standards may even backfire by increasing energy demand.

Brookes (12) uses macroeconomic theory to expand this claim, suggesting that cost-effective energy efficiency improvements may be a form of technological progress that improves productivity, promotes capital investment, enhances economic growth, and ultimately increases energy demand. Saunders (13) uses neoclassical growth theory to assert that the combination of Brookes's growth effect and the rebound effect could overwhelm the demand-reducing effect of increased energy efficiency under reasonable conditions—conditions that may hold in the U.S. economy. Inhaber & Saunders (14) reach similar conclusions with historical evidence, particularly regarding the growth effect. Although these arguments have merit, we find them taken to extreme conclusions with little supporting empirical evidence.

In a review of energy efficiency standards for appliances, Hausman & Joskow (15) list several inherent weaknesses to consider in any evaluation of standards. First, although the minimum energy efficiency of appliances can be mandated by standards, actual energy use is determined by much more uncertain consumer behavior, including issues such as the rebound effect. Uniform national standards do not seem well suited to a country with substantial differences in weather characteristics and energy prices and do not allow for heterogeneity in consumer tastes for energy-using services and appliance choice (e.g., for a consumer who needs air-conditioning only a few days per year, purchasing an inexpensive model with low-energy efficiency may be cost-efficient). When the appropriate level of standards for promoting economic efficiency is uncertain, rigid standards may not be the best option because they are difficult to adapt to new information about consumer behavior and costs.

Sutherland (16, 17) argues that little or no evidence indicates that appliance standards make consumers truly better off and that much of the market failure theory underlying optimistic net benefit estimates is misguided: if such large net benefits could be gained, then consumers would already be taking advantage of them. Sutherland also argues that appliance standards appear to be regressive because their negative impacts are likely to affect low-income households disproportionately.

Although these skeptical authors contend that empirical evidence supports their theoretical findings, they typically do not provide it. Sutherland (18), who provides a numerical sensitivity analysis of the Meyers et al. (10) estimates, finds that assuming significantly higher-discount rates than other studies (e.g., 21% to 28% per year) and greater baseline improvements in energy efficiency results in a lower, and possibly negative, net present value of appliance standards. Sutherland bases these higher-discount rates on several studies of implicit discount rates (19–21).

Refuting the skeptics' contentions, Grubb (22) disputes the policy relevance of the rebound effect, stating that the conditions under which it would be important do not apply to appliance efficiency standards. In an empirical study of the effect of efficiency improvements on residential electricity demand in New York, Dumagan & Mount (23) find the rebound effect numerically unimportant. In a review of 42 field studies, Nadel (24) finds little or no rebound effect in most cases. Stoft (25) criticizes Sutherland's work (16) and suggests that appliance standards are not regressive. Howarth & Sanstad (26) suggest that the energy market is replete with market failures—asymmetric information, bounded rationality, and high transaction costs—and that appliance standards could help to correct for the market failures.

Howarth (27) analyzes the growth effect hypothesis (12–14). According to Howarth's model, energy efficiency improvements would not increase energy use unless two implausible conditions hold: energy costs dominate the total (energy and nonenergy) cost of energy services, and spending on energy services constitutes a large share of economic activity. Weil & McMahon (28) cite several empirical studies that suggest the benefit of well-designed appliance standards.

Nadel (29) observes that energy efficiency improvements stagnate between periods during which new standards take effect (indicating the standards' success) and suggests that some analyses (such as DOE's) overestimate the cost of appliance standards by not considering economies of scale in the manufacture of energy-efficient products. Nadel points to data from other sources, such as the Census of Manufacturers (30), that tend to show more modest appliance cost increases than DOE estimates (which form the basis for the Meyers et al. estimates). For example, census data indicate that the average value per unit of manufacturer refrigerator shipments was $9 lower in 2002 than in 2000, whereas DOE predicted the new refrigerator standard that took effect in mid-2001 would increase manufacturer costs by an average of about $25/unit. Nadel emphasizes that similar trends have been observed in other product standards, indicating that confounding factors are highly unlikely. Nadel also takes issue with the concept that appliance standards are more regressive by observing that appliance standards reduce the cost of more-efficient appliances and force landlords to purchase such appliances (31) and by claiming that both of these results benefit, rather than hurt, low-income households (32).

In a theoretical model, Fischer (33) illustrates the impacts of energy efficiency standards that depend on the structure of the household appliance market. On the one hand, producers may price discriminate and use energy efficiency to segment consumer demand by designing cheap models that underprovide energy efficiency as well as expensive energy-efficient models; thus, appliance standards can improve welfare, even for low-income consumers. On the other hand, a perfectly competitive market would offer the energy efficiency that consumers demand, and appliance standards would not improve welfare. Empirical work is needed to determine which case holds.

Finally, McInerney & Anderson (34) present the manufacturer's perspective on appliance standards: past appliance standards have been cost-effective for and not too much of a burden on manufacturers, but more stringent standards may not lead to similar results.

Although it is difficult to completely reconcile the more critical studies with the responses, differences in assumptions and methodologies underlie the different results. Most of the critiques present theoretical arguments rather than empirical evidence. Sutherland (18) is a notable exception but makes quite different assumptions about discount rates and other key parameters than most other empirical studies. In fact, most empirical studies provide evidence at the state or program level, supporting the cost-effectiveness of appliance standards. Further empirical research would be useful to examine the practical importance of the theoretical criticisms and generalize the results of the many program-level studies.

FINANCIAL INCENTIVE PROGRAMS

Private or public entities can use direct financial enticements to encourage consumers and companies to invest in energy-efficient technology and cut energy demand.

Utility-Based Demand-Side Management Programs

Various demand-side management (DSM) policies attempt to help utilities match energy demand with generating capacity (35). In this context, DSM originally meant actions that utilities would take to change patterns of customer electricity use and thereby modify the pattern of the utility's load (36), but this definition has grown to include the promotion of energy efficiency and conservation (37).

FINANCIAL INCENTIVES FOR CONSUMER PURCHASES After the energy crisis of the 1970s, federal regulators and state public service commissions began implementing utility policies that led to the creation of utility-based DSM programs. The Energy Policy and Conservation Act (1975), Energy Conservation and Production Act (1976), and National Energy Conservation Policy Act (1978) provided encouragement for utility-based conservation and load management programs, as did rulings in favor of DSM by many state utility commissions. The Public Utility Regulatory Policies Act (1978) required state public service commissions to consider energy conservation in rate-making practices, furthering the impetus for utility-based DSM programs (38).

Several strategies have been implemented since the 1970s, starting with *information and loan programs* (to educate consumers and businesses about the cost-effectiveness of energy efficiency measures and to provide low-cost subsidized financing for energy efficiency investments in such measures) and *cash rebates* (for the purchase of designated energy-efficient equipment). Utilities desiring to increase energy savings implemented *comprehensive DSM programs* (which often combined information with financial assistance and direct installation of energy-efficient equipment). *Market transformation strategies* [changes to make more-efficient equipment or energy services the norm (39)] were emphasized in the 1990s when DSM programs became standard operating practice for many utilities. Around the same time, pressure began for *electricity deregulation and restructuring* (allowing independent power producers to sell electricity in wholesale markets and customers to choose suppliers). As DSM funding plummeted in the mid to late 1990s, *public benefit funds* [to finance energy efficiency programs, investments in renewable energy, energy assistance to low-income families, and other designated public benefit activities (40)] were introduced. Estimates of utility-based DSM spending and associated energy savings are listed in Table 1; see Gillingham et al. (2) for details on and discussion of these programs.

The Super Efficient Refrigerator Program (SERP) was a market transformation initiative implemented in the early 1990s, the heyday of DSM. Its general goal

TABLE 1 U.S. Energy Information Administration (EIA) estimates of utility demand-side management (DSM) spending, 1989–2004 (41, 42)

Year	DSM spending US$(2002) millions[a]	Energy savings (GWh)[b]	
		Incremental[c]	Annual
1989	$1,266	NA	14,672
1990	$1,621	NA	20,458
1991	$2,383	NA	24,848
1992	$3,011	6,712	35,563
1993	$3,416	9,002	45,294
1994	$3,297	8,248	52,483
1995	$2,858	8,243	57,421
1996	$2,181	6,857	61,842
1997	$1,834	4,860	56,406
1998	$1,568	3,379	49,167
1999	$1,537	3,103	50,563
2000	$1,635	3,364	53,701
2001	$1,656	4,492	53,936
2002	$1,626	3,802	54,075
2003	$1,268	2,981	50,265
2004	$1,483	4,539	54,710

[a] Spending includes funds on energy efficiency and, to a lesser degree, load management and load building.

[b] Abbreviations: 1 gigawatt-hour (GWh) = 1 million kilowatt-hours (kWh); NA, not applicable.

[c] 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 that participants began the program on January 1 of that year.

was to spur the development of substantially more efficient refrigerators than the then-current models in order to lay a foundation for stronger federal refrigerator standards. The SERP incentive scheme was designed to reward manufacturers for maximum energy savings, minimum incentive payments, and commitment to a speedy delivery schedule.

Twenty-five utilities pledged $30.7 million in DSM funds to SERP. The manufacturer to achieve the most energy savings would receive guaranteed rebates for selling its super-efficient refrigerators in the participating utilities' service areas. Fourteen manufacturers submitted bids, and Whirlpool Corporation won a contract in July 1993 to begin shipping units the following year. By 1998, however, Whirlpool had pulled its line after selling far fewer than their proposed

250,000 units (estimates indicate fewer than 100,000) and earning far less than expected in total incentive payments. Suozzo & Nadel (43) note that Whirlpool's large high-end model was more expensive than most other refrigerators on the market, and its side-by-side design filled a limited market niche. Its size was intentional; the SERP bid scoring system credited the total number (rather than the percentage) of kilowatt-hours saved per refrigerator.

Despite the market failure of its award-winning refrigerator, SERP spurred significant energy efficiency gains in Whirlpool refrigerators and modest gains in other brands (44), and DOE set the 2001 standard for refrigerator energy efficiency at the same level as that of the winning bid. Unfortunately, no SERP evaluation provides *ex post* estimates of energy savings or the program's cost-effectiveness.

ELECTRICITY LOAD MANAGEMENT Electricity load management programs evolved simultaneously with financial incentives for consumer purchases. They aim to limit peak electricity loads, shift peak loads to off-peak hours, or change consumer demand in response to changes in utilities' costs of providing power. All such programs use financial incentives to encourage consumer participation.

- *Direct load control programs* allow a utility to directly control a customer's equipment (typically residential air-conditioning), interrupting power supply during periods of peak system demand, and customers usually receive a rebate or discount on their electric bills.
- *Interruptible load programs* are contracts between a utility and large commercial or industrial customers to interrupt the power supply at any time—during periods of peak demand or when the market price of electricity rises above an agreed-upon rate (38)—by direct control or direct request of the utility system operator.
- *Voluntary demand-response programs* are similar to interruptible load programs but without contractual obligations. Utilities often pay customers for requested load reductions.
- *Real-time pricing tariffs* give customers (mostly industrial, some large commercial) the option to reduce energy demand during peak (high-cost) periods or switch demand to nonpeak (low-cost) periods to reduce electricity bills.
- *Demand bidding programs* allow consumers to specify a reservation bid for a load reduction. When the market-clearing price of electricity is at or above the reservation bid price, the consumer reduces demand by the specified amount in exchange for a payment (45).

Other such programs include funding or subsidizing technologies that shift all or part of a load from one time of day to another or promote the use of distributed generation in response to a signal from the utility.

Only the largest, most flexible consumers have been actively and regularly interested in load management programs (45). Interruptible load and direct load control programs have had few long-term participants, and few consumers are willing to pay prices that vary with wholesale electricity prices in real time. Over time, utilities have shifted to more voluntary demand-response programs in an effort to increase participation. Still, all categories of load management programs are still active and play an important role in utility-based DSM (46).

Among load management programs, direct load control is most likely to reduce total energy use because consumers are unlikely to switch energy use to another time (e.g., a residential consumer whose air conditioner was temporarily shut off during the day is unlikely to increase usage at night). Interruptible load programs are less likely to save energy for industrial manufacturers, which generally reschedule interrupted production. Hence, utility-based DSM spending on financial incentives for electricity load management tends to be more useful for other utility objectives (e.g., shaving peak load) than for saving energy.

DSM COST-EFFECTIVENESS ESTIMATES Information pertaining to the cost-effectiveness of utility-based DSM tends to fall into three categories: *negawatt cost*, utility spending on DSM, or energy savings. Negawatt (or negawatt-hour) cost, used since the late 1980s, typically refers to the full life cycle cost (i.e., total expense of running the program and installing equipment but not the dollar value of electricity savings) per kilowatt-hour (kWh) saved as a result of a DSM program. Negawatt costs are useful for comparing the cost-effectiveness of different DSM programs but require information or assumptions about each program's life cycle.

Estimates of utilities' spending on and energy savings from DSM programs [which utilities have been required to report to the U.S. Energy Information Administration (EIA) since 1989] tend to be annual, and most programs have an up-front cost that generates savings many years into the future, making meaningful comparisons with negawatt cost estimates difficult. The following ranges provide a sense of the state of the literature focused on utility-run DSM programs:

- Negawatt costs are \$0.008–\$0.229/kWh saved.
- Although estimates of energy savings differ by year, total energy savings from all utility-based DSM projects in 2004 were ∼54,710 gigawatt-hours (GWh), and incremental or new energy savings were ∼4,539 GWh per year.
- Estimates of utility-based DSM spending in 2004 were \$1.48 billion (Table 1).

Negawatt Costs Many national studies of the cost-effectiveness of utility-based DSM programs focus on negawatt costs. Nadel (47) estimates utility-based DSM negawatt costs to be \$0.019–\$0.067/kWh saved. (Note: All negawatt costs are reported in 2002 dollars.) In the same general range, Jordan & Nadel (48) find a negawatt cost for industrial rebate programs of \$0.028/kWh saved. Other commonly cited estimates of negawatt costs published in the early 1990s include Lovins and colleagues' (49) \$0.008/kWh saved and the Electric Power Research Institute's (EPRI's) \$0.036/kWh saved (36). Many such estimates compare favorably with the levelized cost of energy (which includes the cost of generation capital amortized over the life of the generating facility) from new generating units in the United States in 1991, which was \$0.067–\$0.133/kWh (48).

Joskow & Marron (50) claim that the true utility cost of purchasing negawatts is substantially higher than the Lovins and EPRI estimates because of the unaccounted-for effects of free riders (i.e., consumers who participate in the program but would have saved energy without the program), underreporting 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., that consumers keep equipment for its useful lifetime rather than retire it early). They suggest that the societal cost of negawatts is often underestimated by a factor of two or more on average.

Several subsequent researchers estimate negawatt costs below the upper bound of Nadel's (47) estimate. For all utility-based DSM programs, Eto et al. (51) find \$0.038/kWh saved. Raynolds & Cowart (52) cite a 1994 EIA study that reports a mean utility cost for energy efficiency programs of \$0.035/kWh saved. In a review, Nadel & Geller (53) provide estimated negawatt cost ranges for the program from two perspectives: utility cost only (\$0.030–\$0.042/kWh saved) and total resources (utility cost plus cost to consumer; \$0.048–\$0.071/kWh saved). The latter estimates are close to what Joskow & Marron (50) suggest would be appropriate.

Finally, in a recent *ex post* study, Loughran & Kulick (54) attempt to resolve the issue of free riders econometrically to produce national negawatt estimates for 1989–1999: \$0.146–\$0.229/kWh saved for the full sample of 324 utilities and \$0.063–\$0.125/kWh saved for a subsample of the larger of these utilities (and presumably more experienced with utility-based DSM programs). In comparison, the utilities estimated an average of \$0.02–\$0.03/kWh saved. They find that the true energy savings from DSM programs typically are smaller than utilities report, leading to higher estimates of negawatt costs. In response, Geller & Attali (55) assert that Loughran & Kulick measured only the initial year's energy savings from efficiency investments, rather than the energy savings over the lifetime of efficiency measures. This would imply that the negawatt cost estimated by Loughran & Kulick is not based on the full benefits of energy efficiency investments and is therefore inappropriate as a measure for judging whether or not utility DSM programs have been cost-effective.

However, we believe this criticism is misplaced and is due to a misunderstanding of the econometric approach taken by Loughran & Kulick. Loughran & Kulick evaluate the effects of lagged DSM spending on changes in megawatt-hours of electricity consumption at the utility level. This differencing approach, which is common in econometrics, is used to control for unobserved factors that vary across utilities that could simultaneously affect both electricity sales and the adoption of energy efficiency policies. Through differencing, Loughran & Kulick better identify the effects of current and recent past DSM spending on energy consumption. One way to conceptualize this approach is that the change in energy consumption from one year to the next is associated with recent investments in energy efficiency because previous investments in energy efficiency would have already affected previous years' energy consumption.

Annual Energy Savings and DSM Spending Although not directly comparable with estimated negawatt costs, estimates of annual energy savings and utility spending provide useful information about the cost-effectiveness of utility-based DSM programs. Hirst (56) states that utilities saved 14,800 GWh in 1989 and 17,100 GWh in 1990, costing utilities $1235 million and $1678 million, respectively. (Note: Unless otherwise indicated, annual savings data in this section include the benefits of past and present utility-based DSM programs.) In 1990, utility-based DSM expenditures accounted for 0.7% of total annual U.S. electricity revenues, with a corresponding energy savings of 0.6% of total annual energy use. Hirst (57) also estimates 1992 energy savings from utility-based DSM programs as 0.5% of total annual energy use.

Additional estimates of energy savings include 32,995 GWh/year for 1990 (58), considerably higher than Hirst's (56); 16,300, 18,700, 23,300, and 31,800 GWh/year, respectively, for 1989–1992 (59); and 27 quads cumulatively for 1973–1998 (52).

EIA estimates of energy savings and spending (Table 1) imply that utility-based DSM programs saved 1.6% of all electric energy consumed in 2001, assuming that all utility-based DSM energy savings are derived from reduced electricity use. Nadel & Kushler (40) modify annual EIA estimates to account for some missing data and add estimates for some prior years; their 20,458-GWh estimate for 1990 falls between those of Hirst (59) and Faruqui et al. (58). More recently, York & Kushler (60) augment EIA utility-based DSM energy savings estimates with energy savings estimates associated with public benefits programs (typically run by state agencies) to find total 2003 savings from electricity DSM programs of more than 67,000 GWh.

Because utilities self-report energy savings, the EIA estimates are far from perfect. Hirst (61) suggests that utilities may define DSM programs differently (e.g., some may include load-building programs in reported data, even though EIA explicitly states that they should not) and that, although improvements have been made in recent years, no single standardized method is used for estimating the effects of DSM programs. Some utilities may use engineering life cycle data, which probably yield higher estimates than in-place lifetime data from surveys or field studies (62). Some utilities may report energy savings at the consumer meter and others at the generator (readings of which differ by 5% to 15%). Finally, whereas most utilities attempt to account for free riders and report the savings that can be attributed directly to the program, others report only total savings. Methods used to account for free riders also differ.

Horowitz (63) claims that utilities have underreported energy savings from commercial DSM programs for 1997–1999 and overestimated the rate of retirement of commercial equipment. Horowitz also suggests that true commercial DSM savings should have been 7.7% higher than reported in 1997 and 17.3% higher than reported in 1998 and 1999.

Interpreting Cost-Effectiveness Estimates The literature reflects many schools of thought about how to best interpret cost-effectiveness values, but a few common threads stand out. Several authors have pointed out shortcomings in the methods used to calculate DSM savings, leading to overestimates of savings or underestimates of costs. Nichols (64) suggests that total resource cost calculations may disregard some costs and benefits (e.g., differences in quality, time spent filling out forms). Nichols thus proposes basing estimates on consumer surplus, which may yield lower net benefits. Several authors suggest there is cause for concern in how utilities handle free riders (65–68), the rebound effect (66), and moral hazard issues (deferring conservation investment to wait for a financial incentive program) (66, 69). The strongest concerns have been over free ridership, with Krietler (67) estimating that up to 80% of energy savings in some programs is from free riders, and the results of Loughran & Kulick (54) implying that adjusting for free riders could reduce energy savings by as much as 50% to 90%. These estimates of the impact of free riders are consistent with findings that roughly 70% of reported energy savings in a Southern California Edison industrial DSM program would have occurred in absence of the program (70) and with similar findings for a Midwest utility (71).

However, there is a significant literature that, although acknowledging these issues in theory, finds in practice energy savings are typically estimated well (e.g., 72–74). Vine & Kushler (75) note that the evaluation of DSM programs may in principle be no more uncertain than the evaluation of supply side resources and that an examination of studies reveals little bias and good levels of precision in the estimates. Goldman et al. (76) point to considerable improvements in recent years in the measurement of energy savings and costs as the industry has become more sophisticated.

Several papers also directly address some of the concerns raised above. Levine & Sonnenblick (77) disagree with Nichols (64), stating that the total resource cost method most accurately represents actual program results and may even underestimate the true benefits of utility-based DSM programs. Sanstad & Howarth (78) draw similar conclusions. Eto et al. (51) posit that additional spillover or “free-driver” effects (which would occur if nonparticipants were induced to invest in conservation because others in the program made such investments) may balance out the free-rider effect in many cases. Indeed, in a recent study, the New York State Energy Research and Development Authority (79) finds that for several DSM programs free drivers more than offset free riders. Eto et al. (80) examine 20 commercial lighting programs, using a methodology similar to that used by Joskow and Marron, and find that all of these programs are cost-effective and do not suffer greatly from Joskow and Marron’s criticisms. Nadel (personal communication) suggests that estimates from well-designed individual programs have modest total DSM costs, even when consumer costs are included. For example, a statewide program in Vermont that serves the residential, commercial, and industrial sectors is estimated to have reduced statewide electricity use by more than 1% per year at an average total cost (utility costs plus customer costs) of about $0.042/kWh [Nadel’s calculations are based on data from Efficiency Vermont (81)].

In a recent work, Geller & Attali (55) provide a comprehensive rebuttal to nearly all of the major criticisms of energy efficiency DSM programs, citing much of the literature. Geller emphasizes that recent programs are designed to mitigate free-rider issues and that spillover and free-driver effects may more than compensate for free-rider effects.

Income Tax Credits or Deductions

Income tax credits or deductions have occasionally been used as a policy instrument to encourage energy conservation. The Energy Tax Act of 1978 (ETA) provided a federal tax credit for residential energy efficiency investments to homes built after 1977 and encouraged residential investment in solar, wind, and geothermal energy technologies. About 30 million claims for conservation tax credits were filed (∼\$166/claim) from 1978–1985, amounting to nearly \$5 billion (in nominal dollars) in lost tax revenues (82). Reagan-era tax reform legislation brought ETA to an early end in the mid-1980s (incentives were designed to expire in 1987). Following two decades without federal tax incentives, the Energy Policy Act of 2005 authorizes tax credits to owners of hybrid vehicles, homeowners who make energy-efficient home improvements, and manufacturers of energy-efficient appliances.

State conservation tax credits or deductions began prior to ETA. For instance, in addition to the federal conservation tax credits that existed from 1979–1985, Arizona, California, Colorado, Hawaii, Montana, and Oregon offered credits and Arkansas, Idaho, and Indiana offered deductions during this period (83). Information from recent state tax forms indicates that six states still offer some type of conservation tax credit or deduction. [For more details on the history of income tax credits and deductions, see Gillingham et al. (2).]

Empirical evidence on the effectiveness of energy conservation tax credits is mixed. Carpenter & Chester (84) find that, although 86.8% of more than 5000 homeowners who responded to a survey were aware of the ETA78 federal tax credit, only 34.5% actually filed a claim between 1978 and 1980, and of those who did, 94% would have invested even without the tax incentive. Using different data from the same survey, Durham et al. (85) econometrically determine that the level of state 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 econometrically estimate the effect of tax incentives on all conservation investment but with different findings: very small and statistically insignificant but positive (86) and slightly negative (87). Hassett & Metcalf (83) identify methodological reasons for these prior findings. First, deduction-based state tax programs may not be correctly accounted for in some early papers. Second and more important, Hassett & Metcalf control for specific individual effects (e.g., conservation "taste" factors and housing attributes) that they claim are likely to be correlated with the explanatory variables (e.g., whether a state introduces a tax credit or deduction) and find that a change of 10 percentage points in the tax price for energy investment increases the probability of making an investment by 24%.

In another econometric analysis, Williams & Poyer (88) find that tax credits play a statistically significant role in explaining improvements related to energy conservation. Like Hassett & Metcalf (83), they imply that despite the presence of free riders, the 1980s tax credits were somewhat effective in spurring conservation investment, perhaps because of spillovers (e.g., the tax credit induced conservation investment by some consumers who then failed to file a claim) (S. Nadel, personal communication).

INFORMATION AND VOLUNTARY PROGRAMS

All the information and voluntary programs considered here attempt to induce energy-efficient investment by providing information about potential energy savings or examples of energy savings.

Section 1605b of the 1992 Energy Policy Act (P.L. 102–485) mandated that DOE create a national inventory of greenhouse gases and a national database of voluntary reductions in greenhouse gas emissions from 1987 forward. The database allows a company to make public commitments to future reductions, set goals, and thereby improve its public image. EIA's cost for 1605b administration was \$1.4 million in 1994, \$1.65 million in 1995, and \$0.44 million in 1998 (89). These costs subsequently leveled off to \$0.46 million for data collection, software updates, and report publication in 2000 (P. McArdle, personal communication).

In 2000, reductions associated with energy efficiency conservation projects that were registered with Section 1605b amounted to 6.083 MMTCE (P. McArdle, personal communication)—an energy savings of about 0.411 quads, calculated using an average nontransportation emissions rate of 14.75 MMTCE/quad (41). Some unknown percentage of these registered emissions reductions probably would have occurred in the absence of the 1605b program. The true amount of emissions reduced by the program probably is between 0 and 6.083 MMTCE.

A voluntary partnership between DOE and national utility trade associations to reduce greenhouse gas emissions, Climate Challenge was launched in October 1993. The program stopped accepting new applicants after 2000; however, DOE still runs it for existing participants, who are encouraged to make new commitments. As of 2000, 124 partnerships with national industry trade associations represented 651 utilities and commitments to reduce carbon emissions by more than 47.6 MMTCE by 2000 (90). Many if not most of these commitments were fulfilled with utility-based DSM programs, so Climate Challenge may have partly encouraged the energy savings and reductions in greenhouse gas emissions associated with utility-based DSM programs.

The 1605b-registered Climate Challenge emissions reductions in 2000 that were not associated with utility-based DSM programs amounted to 12.038 MMTCE (P. McArdle, personal communication)—an energy savings of about 0.814 quads [calculated using an average nontransportation emissions rate of 14.75 MMTCE/

quad (41)]. Like in the 1605b program, the amount of these registered emissions reductions attributable exclusively to Climate Challenge could be 0–12.038 MMTCE.

The U.S. Environmental Protection Agency (EPA) initiated the ENERGY STAR labeling program in response to a provision of the 1992 Energy Policy Act. ENERGY STAR encompasses many voluntary programs designed to encourage consumers to buy energy-efficient models and manufacturers to improve the energy efficiency of their products. EPA and DOE now jointly run the program for more than 35 product categories (e.g., major appliances, office equipment, and home electronics) as well as new homes and commercial and industrial buildings; see Gillingham et al. (2) for a full list.

Several public-private partnerships fall under the auspices of ENERGY STAR: Green Lights (promotes the use of energy-efficient lighting in commercial and industrial buildings), Climate Wise (promotes energy efficiency in commercial and industrial buildings), the Green Power Partnership (encourages organizations to buy renewable energy), the Combined Heat and Power Partnership (builds voluntary cooperative relationships to increase efficiency and decrease energy usage and greenhouse gas emissions), and ENERGY STAR Home Sealing (improves home energy performance when remodeling or renovating). By 2001, ENERGY STAR had facilitated partnerships between the government and more than 7000 public- and private-sector organizations (91).

EPA estimates that several ENERGY STAR activities saved more than 80 billion kWh and avoided the use of 10,000 megawatts of peak generating capacity in 2001 (92). The ENERGY STAR label is widely recognized (by more than 40% of the American public), and more than 750 million ENERGY STAR products were purchased through 2001. More than 57,000 ENERGY STAR–labeled homes have been constructed, reducing energy costs by an estimated $15 million annually. Determining the degree to which these energy savings were induced by the ENERGY STAR program is difficult; some likely would have occurred in the absence of the program.

EPA also estimates the net present value through 2012 of all ENERGY STAR–related investments made through 2001: energy bill savings of US$(2001) 75.9 billion, incremental technology expenditures of $10.7 billion, and net savings of $65.2 billion (92). These savings are associated with an estimated reduction in greenhouse gas emissions of 241 MMTCE.

In recent years, EPA has spent ∼$50 million on administering all ENERGY STAR programs (D. Malloy, personal communication). We found no estimates of costs to consumers who take part in ENERGY STAR programs, but EPA (92) suggests that there are none because reduced energy spending more than makes up for any participation costs.

A few researchers address the cost-effectiveness of ENERGY STAR programs. DeCanio (93) finds that because organizational and institutional factors are important impediments to energy efficiency, voluntary programs such as the Green Lights Program can induce energy-saving investment, improve corporate performance, and reduce pollution. DeCanio & Watkins (94) present similar conclusions in an econometric analysis of Green Lights data.

Webber et al. (95) estimate the cumulative energy savings, undiscounted energy bill savings, and avoided carbon emissions attributable to ENERGY STAR programs [also see Gillingham et al. (2, Table 7)]. In a review, Howarth et al. (96) suggest that Green Lights and other ENERGY STAR programs successfully save energy by reducing market failures related to imperfect information and bounded rationality. They also suggest that the programs do not suffer greatly from the rebound effect (mentioned in the section on appliance standards).

Four DOE programs are dedicated to improving the energy efficiency of buildings and developing voluntary public-private partnerships.

- Building America provides technical assistance to home builders and facilitates dialogue about energy efficiency between segments of the home-building industry that traditionally work independently. As of 2000, this program had been involved in the construction of more than 2000 houses in 24 states (97).
- Rebuild America builds partnerships among communities, states, and the private sector to improve the energy efficiency of any building. According to DOE, the program had involved nearly 500 public-private partnerships by the end of 2002 and engaged in 600 projects in 2001 and more than 800 projects in 2002 (98). Annual energy savings from these projects amounted to 9 trillion Btu, valued at $131 million. Annual pollution reductions (estimated from reduced electricity consumption) were 3349 metric tons of sulfur dioxide (SO_2), 1576 metric tons of nitrogen oxides (NO_x), and 768,239 metric tons of CO_2. Every federal dollar invested in the program saved an estimated $18.43 and generated $9.38 in private investment in energy efficiency (98).
- High Performance Buildings is a research and information initiative between DOE and engineers, architects, building owners and occupants, or contractors to improve the energy efficiency of new commercial (primarily office) buildings.
- Zero Energy Buildings is an initiative to construct superenergy-efficient residential homes that rely on renewable distributed generation for most energy needs, potentially resulting in a net-zero annual energy consumption. DOE has partnered with four home-building teams to further develop the concept and inform home builders.

The last two of these initiatives are small and relatively new, so few assessments of their cost-effectiveness have been published (99).

Partnership for Advanced Technology in Housing

The voluntary Partnership for Advanced Technology in Housing (PATH) teams the U.S. Department of Housing and Urban Development (HUD) with home builders, product manufacturers, insurance companies, and financial companies to improve the energy efficiency, affordability, durability, environmental sustainability, and resistance to natural disasters of residential housing (100).

Energy efficiency is not PATH's only objective but is a primary one. In 2000, PATH set a goal to reduce energy use in 15 million existing residential homes by 30% or more by 2010 (101). An independent review (102) finds this goal laudable but largely unattainable because of other somewhat incompatible goals [e.g., more than 80% of PATH's annual congressional funding—$980,000 in 1998, $10 million in 1999 through 2001, and $8.75 million in 2002—is dedicated to research and development activities (103)]. An evaluation of 56 PATH activities initiated between 1999 and 2001 recommends program improvements but offers no estimated energy or cost savings resulting from the energy efficiency component of the program (103).

Industrial Energy Audits

DOE's Office of Energy Efficiency and Renewable Energy, Industrial Technologies Program, runs two activities primarily focused on industrial energy audits: industrial assessment centers (IACs) and plant-wide assessments (PWAs).

Since 1976, DOE's IACs have encouraged improvements in industrial energy efficiency by conducting free energy, waste, and productivity assessments for small- and medium-sized companies. Teams of faculty and students from 26 U.S. university-based IACs perform ∼25 assessments per university per year, saving the average participating manufacturing facility an estimated $55,000 annually (104). IACs saved an estimated 467 trillion Btu of energy between 1977 and 2001 for an undiscounted cumulative savings of nearly US$2(2001) billion (105). Current program administration costs are about $7 million/year (106).

Manufacturers that are too large to qualify for free IAC audits may qualify for PWAs. Facilities compete for awards of up to $100,000 per proposal to fund energy-efficient investments, of which the manufacturer must pay at least 50%. PWA participants typically save an estimated $1 million or more in energy costs over fewer than 18 months (107).

Little empirical literature evaluates the cost-effectiveness of IACs and PWAs. Tonn & Martin (108) suggest that three IAC benefits influence firms' decision making related to energy efficiency: direct energy assessment, employment of IAC student alumni, and use of energy efficiency information from an IAC website. They also find a significant increase in the number of energy efficiency investments firms made within a short period. Anderson & Newell (106) find that, whereas unmeasured project-related factors influence energy efficiency investments, most plants respond to costs and benefits presented in energy audits; typical investment payback thresholds are 15 months or less (hurdle rate of 80% or greater). They also find that plants reject about half the recommended projects as economically undesirable.

State Programs for Industrial Energy Efficiency

Some states and regional bodies offer industrial programs for innovation and competitiveness, many of which are specifically dedicated to improving energy efficiency. Of ∼300 such programs, some of the most well known are in Iowa, New York, Texas, and Wisconsin. Many state programs coordinate activities through DOE's Office of Energy Efficiency and Renewable Energy, Industrial Technologies Program (109). Because state programs are so numerous and diverse, the literature offers little on the overall cost-effectiveness and energy savings from these programs.

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 (109a) in November 1979. This rule created the well-known EnergyGuide label on which a manufacturer quantifies a specific model's energy consumption and energy efficiency within a range that includes highest and lowest values for comparable models in the market, thus allowing consumers to compare efficiency across models. The label also provides an estimated yearly cost to operate the appliance on the basis of national averages. Major household appliances subject to such labeling include refrigerators and freezers, dishwashers, clothes washers, water heaters, room air conditioners, furnaces, and central air conditioners (5).

Unlike voluntary ENERGY STAR labeling, EnergyGuide labeling is mandatory. Still, the two programs have the same purpose: to provide consumers with information that encourages them to consider energy efficiency in appliance purchasing decisions. Little analysis has been published on whether EnergyGuide's influence on consumer behavior is significant. Weil & McMahon (28) offer anecdotal evidence that such labeling programs can be successful. Newell et al. (110) find that when product-labeling requirements are in effect, increased energy prices encourage manufacturers to offer more energy-efficient products.

In contrast, some literature on utility-based DSM informational programs (6, 111) claims that, in general, labeling programs are fairly ineffective, partly because of a lack of retail compliance with EnergyGuide requirements [e.g., in 2001, the FTC found that in 70 of 144 U.S. showrooms inspected some or all products were unlabeled (112)]. Thorne & Egan (111) suggest redesigning EnergyGuide labels and discuss successful international programs.

Federal Weatherization Assistance Programs

Programs promoting weatherization assistance were among the first federal energy conservation efforts. They primarily help low-income households pay energy bills through the finance and implementation of residential energy conservation investments that result in corresponding energy savings. The combined budget of the two major programs is consistently higher than that of any other federal program funding energy conservation in buildings.

DOE's Weatherization Assistance Program (WAP) was authorized under Title IV of the Energy Conservation and Production Act (P. L. 94-385) in 1976 to help low-income households reduce energy use through weatherization. Approximately 5 million (of nearly 27 million eligible) households have received weatherization services since the program began. Each state sets its own eligibility criteria, with the minimum criterion being a household income below 125% of the poverty line.

A few values help gauge the program's cost-effectiveness. Berry & Schweitzer (113) performed a meta-evaluation of WAP, amassing small surveys to estimate the average net savings of roughly 100,000 homes weatherized annually at 29.1 million Btu/home/year and a total fuel reduction of 21.9%. WAP promotional material (114) expands on this estimate, claiming that, on average, WAP reduces national energy demand by the equivalent of 15 million barrels of oil/year and reduces annual CO_2 emissions by 0.85 metric tons of carbon for natural gas-heated homes and 0.475 metric tons of carbon for homes with electric heat. Avoided energy costs to the 5 million total weatherized households was ∼\$1 billion during winter 2000–2001.

Department of Health and Human Services's Low-Income Home Energy Assistance Program (LIHEAP) was authorized by Title XXVI of the Low-Income Home Energy Assistance Act of 1981. States receive block grants to use for direct home heating and cooling assistance, energy crisis assistance, and home weatherization programs. Up to 15% (usually ∼10%) of LIHEAP funds can be used for weatherization. In fiscal year (FY) 2002, LIHEAP was allocated ∼\$1.7 billion, of which \$201 million (∼12%) was used for weatherization (115). Funds for heating and cooling assistance and energy crisis assistance—which are effectively energy subsidies for low-income households—are more likely to increase than to decrease energy consumption. Thus, LIHEAP probably causes a net increase in energy consumption.

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 PVE funds, so the FY 2002 total was only \$6.9 million. However, even at their peak, PVE funds were never as large a funding source as WAP or LIHEAP. Funding from utility-based DSM programs, state general fund revenues, property owner contributions, and rehabilitation grants for low-income housing weatherization activities totaled an estimated \$122 million in FY 2002 (115).

WAP, LIHEAP, and other funding sources allowed the weatherization of an estimated 186,779 homes in FY 2002 and 200,000–250,000 homes/year in previous years (115). Cumulative energy savings and cost-effectiveness of these activities are difficult to determine.

MANAGEMENT OF GOVERNMENT ENERGY USE

The federal government is the nation's largest consumer of energy products and services (∼\$200 billion/year) and has considerable influence on markets for energy-efficient products. Thus, several programs and regulations have been implemented to promote energy conservation at federal government agencies.

Federal Energy Management Program

DOE's Federal Energy Management Program (FEMP) was established in 1973 to encourage effective energy management in the federal government to save taxpayer dollars and reduce emissions. FEMP offers many types of services to government agencies, including financing for energy-efficient investments and technical assistance (e.g., energy audits).

The FEMP FY 2002 budget was \$24.8 million, more than half of which was allocated to project financing (\$8.7 million) and technical guidance and assistance (\$7.9 million) (116). Little analysis has determined the aggregate benefits and cost-effectiveness of this funding. However, between FY 1985 and FY 2001, the energy intensity of government buildings decreased by 23%; six agencies reduced energy use by more than 20%/gross square foot during that time (116). With total energy use in federal buildings of about 0.3 quads, this reduction amounts to a savings of about 0.07 quads/year relative to a 1985 base. Because of significant changes in government energy use (e.g., military base closings), whether these intensity reductions resulted from technological improvements or simply changes in federal energy use is unclear. How much usage would have changed in the absence of FEMP also is unclear.

Federal Procurement

Federal agencies, which collectively purchase at least 10% of all energy-using products in the United States, are required to choose "life-cycle cost-effective" ENERGY STAR products over other products (117). If ENERGY STAR labels do not apply, then products must be in the upper 25% of the energy efficiency range designated by FEMP.

Harris & Johnson (118) estimate that combined savings from federal energy-efficient procurement policies will be 11 trillion to 42 trillion Btu/year by 2010, representing a reduced energy cost of \$160 million to \$620 million/year or ∼3% to 12% of the year 2000 energy use in federal buildings. Also by 2010, estimated annual savings stemming from energy-efficient purchasing by states, local governments, and schools as a result of the ENERGY STAR Purchasing Program will be 40 trillion to 150 trillion Btu/year. Combined savings are estimated to reduce annual CO_2 emissions by about 2.4 million to 8.6 million metric tons of carbon (about 0.1% to 0.5% of projected U.S. carbon emissions of ∼1.8 billion metric tons of carbon equivalents) by 2010 (119).

SYNTHESIS

Given the limitations of existing information and program data incompatibility, assessing the overall and comparative effectiveness and cost-effectiveness of the energy conservation programs reviewed in this chapter is nearly impossible. We nonetheless searched for and report estimates of annual energy savings and the annual costs of obtaining those savings for 2000 or a proximate year (Table 2).

We report the cost-effectiveness of conservation programs in dollars per quad of energy saved, whenever possible. If information was available from multiple sources (e.g., utility-based DSM), we report a range of cost-effectiveness estimates that can be compared with the value of energy saved, including any additional social value associated with reduced energy-related harm to the environment. In some cases, we calculated estimated annual energy savings or costs from related published data (e.g., multiple-year program costs). We also report estimates of carbon emissions avoided as a result of the reported energy savings. Underlying sources and assumptions (and critical assessment thereof), a detailed explanation of our calculation methods, and caveats and comments appear in Gillingham et al. (2).

Appliance Standards

The equipment cost of energy efficiency investments in any particular year will yield energy savings several years into the future. The annualized economic cost in 2000 of these past investments includes annual depreciation plus financing costs. Unfortunately, the published literature—some of which estimates annual expenditures on energy-efficient equipment—provides no estimates of the annual economic cost in 2000 as we define it.

To calculate annual economic costs in 2000 on the basis of existing estimates, we used the perpetual inventory method commonly used to estimate the capital portion of annual production costs (120). This method considers a consumer's additional expense incurred as a result of appliance standards as a depreciable investment that yields benefits in future years. Results indicate that, on average, the package of appliance standards yields positive net benefits to consumers. Even if unaccounted-for costs of appliance standards are almost equal to those included in the study or if actual energy savings are roughly half of those estimated, appliance standards still would yield positive net benefits on average. Adding the positive environmental benefits of reduced electricity consumption would strengthen the argument that the benefits of appliance standards are worth the cost.

Financial Incentive Programs: Utility-Based DSM

The only financial incentive programs for which we were able to find estimates of energy savings were utility-based DSM programs. The EIA reports not the annual costs associated with all the DSM programs contributing to these energy savings in 2000 but the incremental costs to utilities of new or expanded DSM programs for

TABLE 2 Summary of estimates from existing studies of the effects of energy efficiency programs in 2000

Program	**Date**	**Energy savings in quads**[a]	**Costs US$(2002) billion**[a]	**Cost-effectiveness US$(2002) billion/quad**[a,b]	**Carbon emissions savings (MMTCE)**[a,b,c]
Appliance standards[d]	2000	1.20 (8; J. McMahon)[e]	$2.51 (J. McMahon)[e,f]	$3.28 (2)	17.75 (8, 41)[f]
Financial incentives					
Utility-based DSM	2000	0.62 (41)[f]	$1.78[g] (41)[f]	$2.89[g] (2)	10.02 (41)[f]
Tax incentives		ND	ND	ND	ND
Information and voluntary programs					
Section 1605b registry	2000	<0.41 (P. McArdle)[e,h]	$0.0004 (89)	ND	<6.08 (P. McArdle)[e]
Climate Challenge	2000	<0.81 (P. McArdle)[e]	ND	ND	<12.04 (P. McArdle)[e]
ENERGY STAR	2001	<0.93 (92)	$0.05[i] (D. Malloy)[e]	ND	<13.80 (41, 92)[f]
Rebuild America	2002	0.01 (98)	ND	ND	0.21 (98)
PATH	2000	ND	$0.002[i] (103)	ND	
IACs	~2000	0.02 (105)	$0.007[i] (106)	ND	0.27 (105)
WAP	2003	0.09 (114)	$0.14[i] (114)	ND	1.35 (114)
LIHEAP	2002	ND	$0.20[i] (115)	ND	
Management of government energy use					
FEMP	2002	<0.07 (116)	$0.025[i] (116)	ND	<0.99 (116)
Federal procurement		ND	ND	ND	ND
Total		<4.1			62.5

[a] Reference number is in parentheses.

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

[c] Abbreviations: DSM, demand-side management; ND, no data available; MMTCE, million metric tons of carbon equivalent; PATH, Partnership for Advanced Technology in Housing; IACs, Industrial Assessment Centers; WAP, Weatherization Assistance Program; LIHEAP, Low-Income Home Energy Assistance Program; FEMP, Federal Energy Management Program

[d] Total cost and cost-effectiveness estimates are for residential appliance standards only, whereas energy and carbon savings estimates are for commercial and residential appliance standards. Residential appliances yielded approximately 190.77 quads of energy savings in 2000.

[e] Personal communication

[f] Source of data only; authors' calculations

[g] Value includes only utility costs.

[h] Less than (<) indicates a likely upper bound of energy savings or emissions reductions.

[i] Only direct government administrative costs are included.

each year of the survey (42). Like appliance standards, these utility expenditures typically yield energy savings for many years into the future; so again, we used the perpetual inventory method to develop comparable estimates.

The average electricity price in 2002—a proxy for the average value of energy saved as a result of DSM—was \$6.3 billion/quad. This value is higher than our estimate and many of those in the literature, suggesting that, in aggregate, DSM programs have been cost-effective. However, some published cost estimates (including the EIA data from which our estimate is derived) are based on utility costs only, and accounting for costs to consumers may increase the cost-effectiveness range. A downward adjustment in energy savings to account for free-rider or rebound effects also would increase the range, but an adjustment to account for spillover or free-driver effects could decrease this range.

Finally, utility-based DSM programs are considerably heterogeneous, both in their cost-effectiveness and their methodologies for measuring *ex post* energy savings. The costs reported here combine both high- and low-cost DSM programs; thus, DSM programs with lower costs and larger positive net benefits than our average do exist (see some cost-effectiveness examples in References 79 and 121). In practice, an economically sound strategy would emphasize the DSM activities with the highest cost-effectiveness and eliminate those that decrease average cost-effectiveness.

Information and Voluntary Programs

The largest components of estimated annual energy savings from information and voluntary programs are associated with ENERGY STAR, Climate Challenge, and 1605b voluntary registration of emissions reductions programs; remaining savings estimates are from WAP, IACs, and Rebuild America (see Table 2 and references therein). Cost-effectiveness estimates are not available for any of the informational and voluntary programs.

Management of Government Energy Use

Ex post estimates of government energy reductions, available only for the FEMP, suggest that government energy use has declined (116). However, it is not clear to what extent these savings are the result of the program and would not have occurred otherwise. FEMP probably has saved energy, but no further information is available on which to base a range.

Environmental Benefits

To simplify the calculation of environmental benefits resulting from emissions reductions in Table 3, we assumed that all savings were in the form of electricity. To allow data comparison with Table 2, we used estimates from as close to the year 2000 as possible and assumed that recent policies are in place, providing a sense of what the environmental benefits would be for near-term energy efficiency policies.

TABLE 3 Annual environmental benefits of emissions reductions (circa 2000), with sources of estimates or data[a]

Pollutant	Emissions factor (tonnes/quad)[b]	Cost savings under cap ($/tonne)[b]	Under cap (%)[c]	Environmental benefits ($/tonne)[b]	Percentage not capped	Additional benefit from reduction (billion $/quad)	Increased benefit or "bonus" (%)[d]
CO_2	54,170,611 (118)	ND[e]	0%	8 (2)	100%	0.431	6.80%
NO_x	115,150 (118)	700 (123)	10.6%	1,157 (124)	89.3%	0.128	2.01%
SO_2	234,968 (118)	163.4 (125)	100%	3,857 (124)	0%	0.038	0.61%
PM_{10}	19,973 (118)	ND	0%	2,064 (126)	100%	0.041	0.65%
Total							10.08%
Mercury	13.6 (118)	ND	0%	4,650,000[f]	100%	0.061	1.00%

[a] All dollar amounts are US$(2002).

[b] Reference number is in parentheses.

[c] From authors' calculations

[d] Environmental "bonus" is as a percentage of the 2000 average electricity price of $6.8 billion/quad.

[e] ND, no data available

[f] Amount needed to increase the energy savings benefits by 1%

Although more uncertain than the energy reductions from which they result, total additional benefits of the four pollutants for which we have estimates (CO_2, NO_x, SO_2, and PM_{10}) may be just over 10% of the value of energy savings from energy efficiency policies. A cursory sensitivity analysis with higher values of environmental benefits (in dollars/ton) indicates that doubling the values of our estimated environmental benefits for CO_2, NO_x, SO_2, and PM_{10} would increase the overall results only slightly, from 10% to 20%.

CONCLUSIONS

Along with increasing carbon sequestration and switching to low- and no-carbon fuels, improving the energy efficiency of the economy is a primary avenue for reducing CO_2 emissions associated with fossil fuel combustion. Improved energy efficiency also may serve energy security goals by lessening the effect of fuel supply disruptions and reshaping electricity load profiles to avoid peak-period disruptions.

In researching the role of energy efficiency policies, we quickly encountered 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 future policies. For example, some analysts maintain that greater energy efficiency could substantially reduce carbon emissions at very low, zero, or even negative cost to the U.S. economy (109, 126); many economists are more skeptical.

Bringing together existing estimates of the effects of the energy conservation programs, the literature identifies energy savings of up to 4 quads/year and carbon emissions reductions of up to 63 million metric tons/year (~4% of emissions in 2000), mostly as a result of appliance standards and utility-based DSM programs. ENERGY STAR, Section 1605b, and Climate Challenge programs also may provide large benefits. Including other energy efficiency programs, such as building codes and new research and development, would increase this estimate further.

The literature on appliance standards and utility-based DSM only provides a rough measure of how the average costs of saving energy compare with the average value of those savings. Appliance standards as a group appear to be cost-effective on the basis of existing estimates and typically yield positive net benefits from energy savings alone and additional benefits from ancillary reductions in air pollution. Utility-based DSM programs also appear to be cost-effective using many existing estimates, but the degree to which unaccounted costs to consumers are high (making these programs less cost-effective) remains a topic for further research. The cost-effectiveness of DSM programs also is quite heterogeneous, so some low-cost DSM programs have large positive net benefits, suggesting that eliminating the least cost-effective DSM activities may be beneficial.

Including the additional environmental benefits from reducing CO_2, NO_x, SO_2, and PM_{10} emissions could add ~10% to the value of energy savings from energy efficiency programs. Most of these benefits are derived from CO_2 (7%), with fewer benefits from NO_x (2%), SO_2 (0.5%), and PM_{10} (0.5%). Including environmental benefits strengthens the case for appliance standards and utility-based DSM programs, but not by a large percentage.

The use of energy efficiency policies to reduce energy consumption and carbon emissions over more than two decades and the prospect of expanded and new policies on the horizon suggest that such policies will have a lasting presence. Although existing estimates indicate that policies examined in this paper have had a modest impact, well-designed future policies can potentially further reduce energy and emissions. Estimating the magnitude and cost of such reductions is beyond the scope of this review but remains a fertile area for continued research.

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