Supplementary Information on Energy Efficiency for the National Commission on Energy Policy

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Summary

Previous work prepared for the Commission by Resources for the Future (RFF) examined the savings and economics of past energy efficiency programs and policies. A second study by Lawrence Berkeley National Laboratory (LBNL) estimated the additional savings that can be achieved in the future from new appliance and equipment efficiency standards and building codes. In this short paper I review the results of these two studies and address several issues that complement and supplement these two studies. Key findings are as follows:

1. Both studies do an excellent job of laying out the issues and presenting broad estimates for Commission consideration.

2. Research and development programs and building codes were outside the RFF scope, but both are important enough that they merit Commission consideration. In the case of R&D programs, useful data are provided in a recent study by the National Academy of Sciences, which estimated that DOE's energy efficiency R&D efforts are producing about one quadrillion Btus ("quads") per year of energy savings and producing net benefits of about $30 billion (1999$). A study by the President's Committee of Advisors on Science and Technology estimated that even larger savings can be achieved in the future.

3. For building codes, we conduct analyses of both past savings and potential future savings, concluding that past codes saved about 0.54 quads in 2000 while new codes can save about 0.94 quads in 2020. Our estimate of savings from new codes is nearly twice the savings estimated by LBNL since we base our estimates on current voluntary programs for new homes and commercial buildings (e.g., ENERGY STAR® New Homes and E-Benchmark for commercial buildings) while they look at a more limited set of options.

4. LBNL also estimates savings from new appliance and equipment efficiency standards, with cumulative savings over the 2010–2030 period of about 25 quads. A forthcoming analysis by the American Council for an Energy-Efficient Economy (ACEEE) estimates cumulative savings of about 35 quads over the same period. The difference is largely attributable to several residential products where LBNL either did not include new standards or included only modest new standards. On the other hand, in several cases LBNL examined products not covered by ACEEE. When the LBNL estimates for these products are added to the ACEEE estimates, cumulative savings total 48 quads.

5. RFF estimated that past programs reduced U.S. energy use in 2000 by up to 4 quads. When I add in R&D and building code savings but adjust for overlap between programs and for a couple of optimistic savings estimates in the RFF study, I estimate 4–5 quads of savings in 2000. Dividing by the average period of time each program has operated, programs are saving about 0.6 quads for each year of program operation, which works out to an average of about 1.3–1.6% reduction in buildings energy use for each year of program operation (savings are more modest in industry).

6. Several recent studies estimated the achievable and cost-effective energy conservation potential over the next 5–20 years. The median estimate across these studies is that overall U.S. energy use can be reduced by 1.2–1.4% per year, with slightly higher savings in buildings and slightly lower in industry and transportation. These results for buildings are similar to the historical results.

7. Available data indicate that the economics of energy efficiency programs are generally very favorable. RFF found appliance standards to be very cost-effective and a new but not-yet-published RFF analysis finds utility DSM programs to also be quite cost-effective (i.e., average cost of 3.7 cents per kWh saved). I adjust the discount rate used by RFF to be in line with utility and utility regulator practice and find that DSM programs are saving energy at an average cost of 2.9 cents per kWh, which compares favorably with the approximately 5 cents per kWh cost of power from a new coal or gas power plant. Evidence on the cost-effectiveness of R&D and building code programs is also presented.

8. Energy efficiency programs can also exert downward pressure on energy prices when energy markets are tight, a circumstance that is increasingly common. For example, one recent study found that a 5% reduction in natural gas and electricity use can reduce U.S. natural gas prices by about 20%. Energy efficiency programs can also have positive impacts on employment and the gross domestic product.

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Introduction

The National Commission on Energy Policy (NCEP) has previously commissioned two papers on energy efficiency—a *Retrospective Examination of Demand-Side Energy Efficiency Policies* by Resources for the Future (Gillingham, Newell, and Palmer 2004) and *Energy Efficiency Standards and Codes, Residential/Commercial Equipment and Buildings: Additional Opportunities* by Lawrence Berkeley National Laboratory (Rosenquist et al. 2004). The former examined the impacts of many past and present energy efficiency policies while the latter estimated the savings that can be achieved in the future from two specific policies—equipment efficiency standards and building codes.

Both studies did an excellent job of laying out the issues and presenting broad estimates for Commission consideration. The RFF study is probably the most detailed review of energy efficiency accomplishments published in the past decade and presents and discusses the results of dozens of previous studies on the impacts of various energy efficiency programs. It is a Herculean task and the authors have done a commendable job. Their key conclusion is that past programs have saved about 4 quads (quadrillion Btu) of energy, equivalent to a 12% reduction in buildings energy use. The LBNL study is likewise the most comprehensive summary published to date on future savings opportunities from equipment efficiency standards. They have examined dozens of products and concluded that new standards can save more than 25 quads of energy on a cumulative basis by 2030 (about 1.7 quads per year once the equipment stock turns over[1]).

However, while both studies provide a lot of useful information, there are important issues not addressed by either study, or that are only peripherally addressed by one study or the other. In this paper I address several of these issues in an attempt to complement and supplement the previous two papers. Specific issues addressed are:

- Research and development programs
- Building energy codes—past and future savings
- Equipment efficiency standards—additional opportunities for energy savings
- Putting the RFF savings estimates in context
- Overall future savings opportunities
- Economics of energy efficiency

Research and Development Programs

Research and development (R&D) was deliberately excluded from the RFF report.[2] The authors had a large scope of work, and R&D fell outside this scope. However, R&D has been a key policy strategy of the federal government (and of quite a few states) for several decades and thus it is useful to consider both past accomplishments and future potential. Fortunately, a couple of recent major studies have examined these issues in depth.

[1] Details on this calculation are provided later in this paper.

[2] RFF states: "The focus of this review is on adoption of energy efficient equipment and building practices, rather than on energy research and development." (p. 6).

In 2001, the National Academy of Sciences completed a study entitled *Energy Research at DOE: Was It Worth It?* that reviewed DOE's energy efficiency and fossil energy R&D efforts over the 1978–2000 period (National Research Council 2001). A copy of the key table is included as Table 1 in this paper and found that just six energy efficiency R&D successes have produced 4.88 quads of cumulative savings and saved about $30 billion on net. The Academy committee responsible for this report used the assumption that no more than five years of savings should be counted for any R&D success (the assumption being that all of these successes would be achieved without DOE intervention, but five years later). Thus, the 4.88 cumulative savings works out to 0.98 quads saved in any one year (4.88/5). Some of these savings likely overlap with some of the savings cataloged in the RFF report (e.g., improved refrigerators could be credited under standards and under R&D) but given the nature of the energy-saving measures included in the National Academy study, a substantial portion of the R&D savings are not double-counted. Furthermore, the National Academy only looked at six of DOE's most successful projects (the "big winners") but there are hundreds of other projects, many of which contribute some savings. Overall, based on its review, the Academy concluded that "the benefits of these [DOE energy efficiency] programs substantially exceed the programs' costs and contribute to improvements in the economy, the environment, and national security…"

Table 1. Net Realized Benefits Estimated for Selected Technologies Examined for National Academy of Sciences RD&D Case Studies

	Economic Benefits (Cumulative Net Energy Savings and Consumer Cost Savings)				Environmental Benefits (Cumulative Pollution Reduction)				Security Benefits (Oil Use or Outage Reduction)		
Technology	Cost of DOE and Private RD&D (billion $)[a]	Fuel (Q)[b]	Electricity (Q of primary energy)[c]	Net Cost Savings (billion $)[d]	SO_2 (millions of metric tonnes)	NO_x (millions of metric tonnes)	Carbon (millions of metric tonnes)	Damage Reduction (billion $)[e]	Oil and LPG (Q)[f]	Electricity Reliability	Value (billion $)[g]
Advanced refrigerator/freezer compressors	~0.002[h]		1	7[i]	0.4	0.2	20	1-5	0.04		0.02-0.1
Electronic ballast for fluorescent lamps	>0.006[j]		2.5	15	0.7	0.4	40	1-10	0.1		0.05-0.3
Low-e glass	>0.004[k]	0.7	0.5	8[l]	0.3	0.2	20	0.5	0.2		0.1-0.7
Advanced lost foam casting	0.008		0.03	0.1[m]	0.01	0.006	0.5	0.02-0.1			
Oxygen-fueled glass furnace	0.002	0.06		0.3		0.02	1	0.05-0.2			
Advanced turbine systems	~0.356	0.09		~0 by 2005[n]		0.02	1	0.05-0.2		Yes	
Total	~0.4			~30				~3-20			0.2-1

In addition to DOE's R&D efforts, there are many other public sector R&D programs such as those led by states (e.g., the New York State Energy Research and Development Authority and the California Energy Commission's Public Interest Energy Research program) and other research institutes (e.g., the Electric Power Research Institute and the Gas Technology Institute). A few of the major state efforts were profiled in a report prepared for the

Association of State Energy Research and Technology Transfer Institutions (Pye and Nadel 1997). These programs also contribute significant savings.

Looking to the future, in 1997 the President's Committee of Advisors on Science and Technology issued a report on *Federal Energy Research and Development for the Challenges of the Twenty-First Century* (PCAST 1997). The Committee concluded that federal R&D investments in energy efficiency should be nearly doubled from 1997 levels (e.g., from $450 million to $880 million in 1997$) and that such investments could save more than $40 billion per year and reduce annual carbon emissions by 250 million metric tonnes, both by 2010. These potential future savings are substantially larger than the savings achieved over the 1978–2000 period as calculated by the National Academy. PCAST concluded that "[t]his large increase is appropriate because of the high promise of advanced efficiency technologies for relatively quick-starting and rapidly expanding contributions to several important societal goals, including cost-effective reductions in local air pollution and carbon dioxide emissions, diminished dependence on imported oil, and reductions in energy costs to households and firms." While the tight federal budget has resulted in much smaller budget increases than PCAST recommended, the general conclusion from PCAST was that new R&D investments can result in substantial energy and economic savings.

Building Energy Codes

Building energy codes were also excluded from the RFF report.[3] However, building energy codes have also been an important policy strategy since the 1970s and it is important to understand their impacts. My organization, the American Council for an Energy-Efficient Economy (ACEEE), is not aware of any studies that attempted to estimate the national savings from building energy codes, so we have prepared a rough analysis on this issue that is presented in Table 2. For this analysis, we focused on code improvements developed in the late-1980s and early 1990s, improvements that have now been adopted in most states. We looked at new construction during the 1990s and applied savings from model codes to this construction in those states that have adopted these model codes. Overall, we estimate that these codes reduced U.S. energy use by about 0.54 quads in 2000. This estimate is just a "ballpark" estimate as it: (1) ignores any savings from codes adopted in the 1970s or 1980s; (2) ignores savings from codes that exceed the national minimums (e.g., California, Florida, Massachusetts, Minnesota, New York, Oregon, Washington, and Wisconsin have long histories of exceeding national model codes); and (3) assumes all states that presently have adopted the model codes did so as of 1990, even though adoption was gradual throughout the 1990s. Implicitly, we are assuming that the first two factors counterbalance the third factor, an admittedly imprecise assumption.

[3] RFF states: "We further limit the scope of the study by omitting building codes, professional codes, and Corporate Average Fuel Economy (CAFÉ) Standards to focus on the remaining programs (p. 6-7).

Table 2. Estimated National Savings from Building Code Improvements

	Electricity (TWh)	Fuels (Trillion Btu)	Savings from New Code (%)	Proportion of U.S. Construction New Code Applies To (%)	Savings in 2000		
					Electri-city (TWh)	Fuels (Trillion Btu)	Total (Trillion Btu)
Residential	91	725					
Adoption of 1992 CABO MEC or beyond			18%	80%	16.0	127	306
Commercial	122	332					
Adoption of 90.1-1989 or beyond			15%	77%	16.6	45	230
TOTAL					32.6	172	537

Notes:
* Baseline energy use from 2001 Residential Energy Consumption Survey (EIA 2004c) and 1999 Commercial Energy Consumption Survey (EIA 2002). We include space heating, space cooling, water heating and lighting using end-use estimates from these EIA surveys.
* Total energy use numbers in Btu combine direct combustion plus the fuel burned to generate electricity and assume heat rate from Annual Energy Outlook 2003 (EIA 2003) of 1,1181 Btu/kWh in 2000.
* Residential energy savings derived by W. Prindle from Howard and Prindle (1991). Commercial energy savings from Pacific Northwest National Laboratory analysis for DOE.
* Portion codes currently apply to estimated by W. Prindle and S. Nadel based on current code status and residential housing starts and non-residential construction activity by state.

Probably more importantly, there is a very large potential for future energy savings from building codes. LBNL in its report for the Commission attempted to estimate the potential for these future savings. Overall, LBNL estimated potential cumulative energy savings through 2030 from improved building codes to be 5.2 quads. This is equivalent to approximately 0.5 quads in 2030.[4] However, LBNL only examined particular technologies and appears to have missed some significant technical opportunities such as residential duct sealing, reductions in lighting energy use beyond the current ASHRAE standard, and improvements in HVAC equipment efficiency and controls/systems design. In addition, by looking only at individual technologies, a variety of system interaction effects appear not to be included. Much of the remaining savings opportunity is through better systems design and not through use of individual technologies (Johnson and Nadel 2000).

In order to address these limitations, ACEEE prepared an analysis to estimate the energy that can be saved by 2020 by policy interventions to bring energy codes up to the level of today's major voluntary residential and commercial new construction programs, such as the ENERGY STAR New Homes program and the New Buildings Institute E-Benchmark guideline for commercial buildings.

[4] Savings from codes gradually ramp up as buildings are built. The LBNL estimates cover 20 years, but savings start at zero and gradually climb to double the 20-year average. Thus we can estimate annual savings in 2030 by dividing the LBNL cumulative estimate by 20 and multiplying by two.

Specifically, for new homes, we analyzed the savings from bringing codes from current levels to levels needed to achieve the ENERGY STAR Homes designation in states representing 75% of new construction. Depending on region, 15–30% energy savings are needed to go from current code levels to ENERGY STAR levels. We assume average savings of 20%. We further assume that these code improvements are implemented in three stages, corresponding to the 2006, 2009, and 2012 editions of the International Energy Conservation Code (IECC—the major model code). We assume that states on average take three years to adopt the IECC (e.g., some states will adopt the 2006 IECC in 2006, some in 2012, but on average, the 2006 code is adopted in 2009). For the 20% of construction that is not covered by current codes, we assume that these are eventually brought up to current code levels, but that these states will not go beyond current codes. Finally, we also assume that enforcement of existing codes is improved, resulting in 2% savings in those states that improve enforcement. Sources of data that support these assumptions are documented in Table 3.

For new commercial buildings, we made generally similar assumptions, except that the long-term target is set by the E-Benchmark, a level of performance that reduces energy use about 15% relative to the ASHRAE 1999 standard (NBI 2003). We estimate that half these savings are included in the 2004 ASHRAE standard (recently approved), and the other half will be incorporated into a 2012 standard. As with new homes, we limit this advanced code to 75% of new construction, and assume that the other 15% not now using the 1999 standard will only be brought up to the 1999 standard. We also include 2% savings from improved code compliance. Data and sources are documented in Table 3.

Overall, based on these assumptions, we estimate that improved building codes can reduce U.S. energy use by about 0.94 quads in 2020, which represents 2.0% of 2020 residential and commercial primary energy use as estimated by EIA (2004a). In order to adopt these codes, extensive education, training, and promotion efforts will first be needed to build market share for the ENERGY STAR and E-Benchmark specifications (or their equivalent), which will build support for eventually incorporating these specifications into codes.

Additional Opportunities for Equipment Efficiency Standards

RFF conducted an extensive review of past achievements from appliance standards and I have nothing significant to add. LBNL also conducted an extensive analysis of savings available from new appliance and equipment standards. Overall, LBNL estimated that new standards on more than two dozen products can save more than 25 quads of energy on a cumulative basis by 2030, which is approximately 1.7 quads per year once the equipment stock turns over.[5] ACEEE is now completing an analysis of savings available from new

[5] Savings from standards gradually ramp up as equipment is replaced, and then level off once all equipment has been replaced. Assuming a 10-year average equipment life, savings ramp up over 10 years and then are steady for the final 10 years. To approximate annual savings once the equipment stock has been replaced, we take the 20-year savings estimated by LBNL and divide by 15, where 15 is based on 10 years of level savings plus 10 years of gradually growing savings, which can be approximated as half this number of years (10/2) of steady savings.

Table 3. Potential National Savings from Building Code Improvements

Code	2020 Energy Use from Construction in 2006-2020		Sav-ings from New Code (%)	Pro-portion of U.S. New Code Applies To (%)	Median Date of Enact-ment	Savings in 2020			Typ-ical Simple Pay-back
	Elec-tricity (TWh)	Fuels (Tril. Btu)				Elec-tricity (TWh)	Fuels (Tril. Btu)	Total (Tril. Btu)	
Residential	130	1292							
Adoption of 2003 IECC in remaining states			18%	20%	2008	3.8	37	76	8
Adoption of 2006 IECC			5%	80%	2009	3.8	38	78	
Upgrades to IECC circa 2009			7.5%	80%	2012	4.2	41	85	
Upgrades to IECC circa 2012			7.5%	80%	2015	2.6	26	53	
Improved code compliance			2%	60%	2010	1.0	10	21	
Subtotal						15.4	153	312	
Commercial	485	1881							
Adoption of 90.1-1999 in remaining states			6.4%	40%	2008	9.9	39	142	4
Adoption of 90.1-2004			7.5%	77%	2009	20.5	80	293	
Upgrades to 90.1/IECC circa 2012			7.5%	77%	2015	9.3	36	133	
Improved code compliance			2%	60%	2010	3.9	15	55	
Subtotal						43.7	169	623	
TOTAL						59.1	322	935	

Notes:
* Baseline energy use in 2020 from *Annual Energy Outlook 2004* (EIA 2004a). We include space heating, space cooling, water heating and lighting using end-use estimates from EIA's 2001 RECS (EIA 2004c) and 1999 CBECS (EIA 2002) surveys.
* For residential sector, new construction proportion based on 1.518 million housing starts per year (avg. for 1993–2002 from U.S. Census Bureau (2003). For commercial, new construction proportion based on floor area for "new additions" in EIA (2004a).
* Total energy use numbers in Btu combine direct combustion plus the fuel burned to generate electricity and assume heat rate from EIA (2004a) of 10,377 Btu/kWh in 2020.
* Savings for 2004 and 2006 codes estimated by W. Prindle and S. Nadel based on portions of these documents that have been approved. Savings from 2004/2006, 2009, and 2012 codes assume a gradual ramp-up to current ENERGY STAR levels for residential (20% savings) and NBI E-Benchmark levels for commercial (average of 15% savings across different building types (NBI 2003). Code compliance savings assume one-third of the buildings are not in compliance (Smith and Nadel 1995) and that due to non-compliance, one-third of the savings code upgrades are lost.
* Proportion of U.S. new code applies to based on percent of new construction currently covered by relatively up-to-date codes (from Table 2).
* Simple paybacks estimated by ACEEE based on data from a variety of sources on costs and savings.

standards that covers many of the same products, but also additional products. In the ACEEE analysis, like the LBNL analysis, the only standards included are those that are cost-effective to consumers on a life-cycle cost basis. A comparison of the LBNL and ACEEE analyses can be found in Table 4. Where both LBNL and ACEEE analyzed the same products and standards, the results are roughly aligned. However, often ACEEE looked at different products than LBNL, and in some cases ACEEE also looked at stronger standards than LBNL. And in some cases, LBNL looked at products not included in the ACEEE analysis.

Overall, ACEEE found about 10 quads more of cumulative savings than LBNL (38% higher savings). The difference is essentially accounted for by four residential products—residential air conditioning (ACEEE assumes a new standard for central air conditioners in the next decade, LBNL does not include a revision); residential lighting (ACEEE includes consensus standards on ceiling fan light kits and CFLs recently negotiated with industry, LBNL does not include these products); residential refrigerators (LBNL assumes a modest new standard, ACEEE assumes a new standard based on the best current major manufacturer products); and residential furnaces (LBNL includes a modest new standard, ACEEE also includes a standard on furnace fans and a standard requiring condensing furnaces in cold climates).

However, even the ACEEE estimate is probably conservative, as ACEEE did not include several products that are included in the LBNL analysis including additional commercial heating and air conditioning equipment (boilers, chillers, water-source heat pumps, PTACs, and cooling towers), electric heat pump water heaters, miscellaneous residential electronic products, office equipment, and supermarket and walk-in refrigeration systems. When the LBNL savings estimates for these products are added to the ACEEE estimates, the estimated cumulative savings total 48.3 quads (see the "Combined" column in Table 4).[6] This is about 3.2 quads per year once the equipment stock turns over, which is 6.2% of 2025 residential and commercial primary energy use as estimated by EIA 2004a.[7]

Putting the RFF Savings Estimates in Context

As noted above, RFF concludes that previous efficiency policies and programs saved as much as 4 quads of energy in 2004. To this figure, we recommend that our estimates of savings from R&D (0.98 quads) and building codes (0.54 quads) be added. This brings the total to about 5.5 quads, although there is likely some double-counting and optimistic estimates included in these figures (e.g., the estimates cited by RFF for the 1605b registry and DOE Climate Challenge seem optimistic). Overall, I would estimate that actual savings from programs and policies fall somewhere in the range of 4 and 5 quads, which represents between 5.5 and 6.9% of 2000 non-transportation energy use and between 11 and 13% of 2000 buildings energy use (as noted by RFF, a substantial majority of the savings are in

[6] However, there is some overlap between the ACEEE estimate of future savings from building codes and the LBNL estimate of savings from standards, as ACEEE included many types of commercial HVAC equipment under building codes while LBNL included them under standards. Therefore, the ACEEE estimate of savings from building codes and the combined estimate of savings from standards should not be summed.
[7] We use 2025 in this case because it will take this long for the stock to turn over for most of the products affected by these standards.

Table 4. Comparison of LBNL and ACEEE Estimates of Savings from New Standards

End-Use	30 Yr. Cumulative Savings (quads)			LBNL vs. ACEEE	Notes/Explanation of Differences
	LBNL	ACEEE	Com-bined	Differ-ence	
Residential					
Gas space heating	1.10	2.30	2.30	1.20	ACEEE included condensing furnaces in cold states.
Air conditioning	0.10	5.77	5.87	5.67	ACEEE looked at a new central A/C standard, LBNL only considered room A/C.
Refrigeration	0.92	2.56	2.56	1.64	LBNL assumed standard less stringent than current ENERGY STAR; ACEEE assumed standard based on best mass production units now on the market.
Lighting	1.90	6.65	6.65	4.75	LBNL only included torchieres; ACEEE also included ceiling fan light kits and CFLs per negotiated agreements with manufacturers.
Water heating	2.80	0.00	2.80	-2.80	LBNL examined heat pump water heaters, ACEEE did not.
Dishwashing	0.13	0.46	0.46	0.33	LBNL assumed standard less stringent than current ENERGY STAR; ACEEE used current ENERGY STAR.
Motors	0.48	3.40	3.88	2.92	LBNL examined ceiling fans and pool pumps, ACEEE examined furnace air handlers.
Misc. electronics	4.50	2.29	4.50	-2.21	LBNL included more products such as audio equipment, telephony, and a misc. category.
Subtotal	11.93	23.42	29.01	11.49	
Commercial & Industrial					
Space heating	0.71	0.86	1.57	0.15	Examined different products—LBNL covered furnaces & boilers, ACEEE covered unit heaters.
Air conditioning	3.02	2.67	3.02	-0.36	LBNL included more products such as chillers, water-source equipment, and PTACs.
Ventilation	0.66	0.00	0.66	-0.66	ACEEE did not include in its study.
Water heating	0.25	1.47	1.72	1.22	ACEEE examined pre-rinse spray valves based on pending CEC standards; LBNL did not.
Lighting	3.10	3.77	3.77	0.67	LBNL and ACEEE examined a somewhat different list of products.
Refrigeration	4.52	0.76	4.52	-3.76	LBNL included central systems (e.g., for supermarkets) and walk-ins; ACEEE did not.
Office equipment	1.55	0.00	1.55	-1.55	ACEEE did not include in its study.
Miscellan-eous	0.00	0.18	0.18	0.18	ACEEE examined commercial clothes washers, LBNL did not.
Distribution transformers	0.00	2.29	2.29	2.29	LBNL did not include in its study.
Subtotal	13.81	12.00	19.28	-1.81	
TOTAL	25.74	35.42	48.30	9.68	

Notes:
* LBNL estimates from Rosenquist (2004).
* ACEEE estimates from Prindle (2004).
* "Combined" column includes all products looked at by LBNL and ACEEE. Where either LBNL or ACEEE looked at more products, this column shows the savings estimate that includes more products. Where LBNL and ACEEE looked at different products, this column sums the LBNL and ACEEE estimates.

buildings). Many observers would probably characterize these as significant but not dramatic numbers. Please note that these figures are for savings caused by programs and policies and do not include efficiency gains caused by normal market forces. If market-induced efficiency gains were also included, the totals would be higher.

Of perhaps greater importance is what do these savings numbers tell us about the savings that can be achieved in the future? To investigate this question, it is useful to convert the savings achieved in 2000 into incremental savings achieved each year. RFF does for the most part provide the periods covered by each savings estimate. These figures, along with the RFF savings estimates, are summarized in Table 5. If we take the savings in 2000 and divide by the number of years required to achieve these savings, we obtain savings per year for each policy. The net result is up to 0.5 quads saved per year just using the RFF results, and up to 0.6 quads saved per year if we include R&D and building codes. This works out to be about 1.3–1.6% of buildings energy use each year (see Table 5).

These figures imply that if we continue energy efficiency efforts at current levels, we can reduce energy use by about 5 more quads in 10 years and 10 more quads in 20 years, which represents roughly a doubling and tripling, respectively, of the savings from efficiency programs achieved to date.

Table 5. Translating RFF Estimate of Effects of Energy Efficiency Programs into an Incremental Annual Savings Rate

Program		Energy Savings (quads)	% of 2000 Buildings Energy Use	Period Covered	Number of Years		Savings Per Year (quads)	% of 2000 Buildings Energy Use
Appliance standards		1.200		1990-2000	10		0.120	
Utility DSM		0.626		1989-2000	11		0.057	
1605b registry	<	0.411		1993-2000	7	<	0.059	
DOE Climate Challenge	<	0.814		1994-2000	6	<	0.136	
ENERGY STAR	<	0.933		1994-2001	7	<	0.133	
DOE Rebuild America		0.009		1994-2002	8		0.001	
Industrial Assess. Centers		0.019		1976-2000	24		0.001	
Weatherization Assist. Program		0.087		1977-2003	26		0.003	
FEMP	<	0.067		1973-2002	29		0.002	
RFF total	<	4.166	11.1%		8.1	<	0.512	1.36%
Building codes		0.560		1990-2000	10		0.056	
R&D		0.976		1978-2000	22		0.044	
Enhanced total	<	5.702	15.2%		9.3	<	0.613	1.63%

Notes: Energy savings and period covered from Gillingham, Newell, and Palmer (2004) except for building code and R&D figures that come from Tables 1 and 2 of the present paper. Buildings energy use in 2000 from EIA (2003).

Overall Future Savings Opportunities

Of course, projecting from past trends is only one way to estimate the potential for future energy efficiency savings. Many recent studies have also estimated the savings that can be achieved from energy efficiency programs and policies over the next 10–20 years. A report by Nadel, Shipley, and Elliott (2004) summarized the results of 11 recent studies (a copy is attached to this paper). Studies of energy savings potential tend to estimate one or more of three types of potential: technical potential (what can be achieved without considering economics), economic potential (what can be achieved from measures that are cost-effective), and achievable potential (what can be achieved from specific cost-effective programs and policies). Over the different studies examined by Nadel, Shipley, and Elliott (2004), the median technical savings potential was 36%, the median economic savings potential was 21.5%, and the median achievable savings potential was 10.5%. However, the studies also varied in the time frame covered, which makes it difficult to interpret this raw data. To address this problem, the authors also calculated the achievable potential per year and found a median achievable potential of 1.2% per year. In general, savings potentials were found to be somewhat higher than this average for the residential and commercial sectors and somewhat lower than this average for the industrial sector. Overall, these results are consistent with the historic results.

Similarly, in 2001, ACEEE conducted a study that estimated the energy efficiency savings that can be achieved in 2020 if nine key policies were adopted (Nadel and Geller 2001). Specific policies, listed in order of the amount of savings that could be achieved, are:

1. Increase Corporate Average Fuel Economy;
2. Adopt a national system benefit trust fund;
3. Enact new equipment efficiency standards and strengthen existing standards;
4. Enact tax incentives for highly efficient vehicles, homes, commercial buildings, and other products;
5. Expand federal energy efficiency R&D and deployment programs;
6. Promote clean, high-efficiency combined heat and power systems;
7. Voluntary agreements and incentives to reduce industrial energy use;
8. Improve the efficiency and reduce the emissions of the existing power plant fleet; and
9. Greater adoption of current model building energy codes and development and implementation of more advanced codes.

This study estimated that these policies could reduce U.S. forecasted energy use by 34 quads in 2020, a reduction of 26% from forecasted levels. Savings were highest in the commercial sector (31%), lowest for transportation (16%), and in-between for the residential and industrial sectors (25% and 19% savings, respectively). This study also examined the costs and benefits of these policies and found that benefits were 2.2 times greater than costs. The study assumed implementation over an 18-year period, which works out to average savings of 1.4% per year across all sectors, with savings of 1.5% per year for buildings (residential and commercial), 1.1% per year for industry, and 0.9% per year for transportation. The buildings figure is in line with the historic results for the buildings sector from the RFF study.

Economics of Energy Efficiency

RFF reviews the economics of two major policies to reduce energy use—appliance efficiency standards and utility DSM programs. In the case of appliance standards RFF found that standards cost consumers an average of about $2.63 billion per quad of savings, which is less than half of the average 2000 electricity price of $6.34 billion per quad (most of the savings from standards are in electricity). This implies a benefit-cost ratio of about 2.4.

In the case of utility DSM programs, the first two drafts characterized these programs as being of borderline cost-effectiveness, with an average cost of about 6.5 cents per kWh saved. However, in response to comments on the earlier drafts, RFF discovered several errors in its calculations. The latest estimate is that these programs cost an average of about 3.7 cents per kWh saved. This estimate from RFF is provided in Table 6. RFF's estimate of a cost of 3.7 cents per kWh is significantly less than retail electric prices in all sectors, which in 2003 was 7.4 cents per kWh for all customers on average (ranging from 4.95 cents in the industrial sector to 8.71 cents in the residential sector [EIA 2004b]). This DSM cost is also less than the marginal cost of new electric generation (which EIA estimated to be about 5 cents per kWh for both "advanced coal" and "advanced combined cycle" gas in EIA [2004a]). However, even this latest RFF estimate is probably somewhat high as it uses a 9% real discount rate in the calculations, which is higher than the 1.7–7.0% rates now generally used by utilities and state utility commissions when preparing resource plans and evaluating DSM programs (current assumptions for a sample of utilities and states are provided in Table 7). If we take an average value from Table 7, which is a discount rate of about 4.5% real, then the average cost of DSM using the RFF spreadsheet becomes 2.9 cents per kWh, very much in line with other recent assessments of DSM programs (e.g., Kushler, York, and Witte [2004] and Cowart [2001] both found an average cost of DSM of about 3 cents per kWh saved).

Other energy efficiency policies can be equally cost-effective. For example, the National Research Council (2001) study discussed above found that DOE's energy efficiency RD&D efforts have resulted in net energy cost savings of about $30 billion (1999$) at a cost of about $7 billion (also 1999$, including DOE and industry costs), implying a benefit-cost ratio of more than 5:1.[8] And evaluations of building codes have found a typical benefit-cost ratio of 3.0 for residential codes (Howard and Prindle 1991) and even higher for commercial codes (Nadel and Geller 2001).

Furthermore, all of these estimates assume that energy efficiency does not affect energy prices or the economy as a whole. In fact, energy efficiency can often have positive impacts on energy prices and the economy.

Regarding energy prices, basic economic theory holds that when supplies are tight (as they often are for oil, gas, coal, and electricity), reductions in demand will cause prices to decline. To provide just one illustrative example, in 2003, Energy and Environmental Analysis (EEA), Inc. conducted two parallel studies on the U.S. natural gas market, one for the National Petroleum Council (NPC 2003) and one for ACEEE (Elliott et al. 2003). The two studies

[8] They found $30 billion net savings after subtracting the costs. This means benefits total $37 billion, which when divided by the $7 billion in costs is a benefit-cost ratio of 5.3.

used the same EEA model. The NPC study looked primarily as different sources of natural gas supply. The ACEEE study looked at the impacts of energy efficiency programs on natural gas prices. Specifically, the ACEEE study assumed that efficiency programs are operated that reduce natural gas and electricity use by an average of about 5% over a five-year period (with higher savings in states already familiar with such programs and lower savings in states that lack experience with these programs). Electricity savings are important because natural gas is frequently the marginal generation fuel. The EEA model estimated that if such efficiency programs are operated nationally, average natural gas prices would decline about 20% over the five-year period relative to a base case scenario without efficiency programs. Even if efficiency programs are only operated in a single region, the study found that average regional natural gas prices would decline about 5% over the period (Elliott et al. 2003). When these benefits are factored into the calculations, the net costs of efficiency can decline substantially. However, the exact amount of price decline will depend on the markets involved and can only be estimated with sophisticated models, a level of effort beyond both RFF's and my scope.

Table 6. Revised RFF Analysis of National DSM Cost Effectiveness

	Computation of DSM Capital Stock				**Computation of DSM Cost-effectiveness**			
Year	CPI (inflation index)	I(t) (nominal DSM spending $M)	I(t) (DSM spending in $2002 M)	K(t) (DSM capital in $2002 M)	Annual cost of DSM capital ($2002 M)	Total annual energy savings (GWh)	Energy efficiency DSM cost effectiveness ($/KWh)	Energy efficiency DSM cost effectiveness ($B/quad)
1989	124.0	$595	$869	$869				
1990	130.7	$802	$1,112	$1,886				
1991	136.2	$1,229	$1,636	$3,314				
1992	140.3	$1,599	$2,067	$5,016				
1993	144.5	$1,927	$2,418	$6,882				
1994	148.2	$1,918	$2,347	$8,471				
1995	152.4	$1,701	$2,024	$9,563				
1996	156.9	$1,232	$1,424	$9,935				
1997	160.5	$1,084	$1,224	$10,067	$2,013	55,453	$0.036	$3.11
1998	163.0	$883	$982	$9,942	$1,988	48,775	$0.041	$3.50
1999	166.6	$934	$1,016	$9,864	$1,973	49,691	$0.040	$3.40
2000	172.2	$1,061	$1,117	$9,896	$1,979	52,827	**$0.037**	**$3.21**
2001	177.1	$1,234	$1,263	$10,071	$2,014	52,946	$0.038	$3.26
2002	181.3							

Derivation of rental price of capital
 = depreciation rate
 = 11% depreciation rate (used to compute DSM Capital)
r = 9% elect. utility cost of capital in 2000 (i.e., discount rate)
+r = 20% rental price of capital
Source: Newell (2004)

Table 7. Current (July 2004) Utility Discount Rates Used in DSM Filings and Plans

Utility	Rate	Type	Source
National Grid USA			
Mass. Electric	4.41%	nominal	Mass. DTE decision 98-100
	1.86%	real	Same as above and 2.5% inflation
Naraghansett Electric	4.96%	nominal	Per PSC, based on 30 year T-Bill rate on 1/02/03
Granite State Electric	4.25%	nominal	Per PUC, based on prime rate
National Grid average	4.54%		
PacifiCorp (OR & UT)	7.79%	nominal	For cost-of-service regulation, from PacifiCorp Resource Plan, 2000
	9.70%	nominal	For merchant plans, from PacifiCorp Resource Plan, 2000
	8.75%	nominal	Midpoint of above two estimates
PG&E	8.15%	nominal	CPUC decision D-01-11-066
Average of 3 companies	7.15%	nominal	
	4.53%	real	Assuming 2.5% inflation as per Massachusetts

Similarly, many studies have found that efficiency investments generally have a positive impact on the economy, such as increases in GDP and employment (see, for example, Geller et al. 1992; Laitner, Bernow, and DeCicco 1998; Nadel et al. 1997; Prindle et al. 2004). These net benefits can be attributed to several factors including: (a) efficiency investments tend to be more labor-intensive than traditional supply-side energy industries; (b) reductions in energy bills free up money for spending in services and other relatively labor-intensive sectors of the economy; and (c) some of our energy is imported and therefore declines in U.S. imports have positive effects domestically and adverse effects beyond our borders. However, while these impacts can be significant, quantifying them more specifically is beyond the scope of this paper.

Conclusion

The RFF study shows that past energy efficiency programs have achieved significant energy savings, and for appliance standards and utility DSM programs, these savings appear to be very cost-effective (the economics of the other programs weren't examined).[9] Overall, RFF estimated that past energy efficiency programs reduced U.S. energy use by about 4 quads in 2000. In this paper we have shown that significant cost-effective savings have been achieved by R&D efforts and building energy codes, resulting in total savings of as much as 5.5 quads in 2020. However, if we allow for some overlap in savings between programs and also for the fact that a few of the program estimates included in the RFF paper are likely optimistic, total savings in 2000 were most likely in the range of 4–5 quads. If we divide by the weighted average period of time each program has been operating, these savings amount to

[9] Early drafts of the RFF study found DSM to be of borderline cost-effectiveness, but the most recent RFF analysis estimates average costs of about 3.7 cents per kWh saved. Using RFF's methodology and data, but adjusting the discount rate, we estimate average costs of about 2.9 cents per kWh saved.

1.3–1.6% of buildings energy use for each year of program operation (savings in the industrial sector appear to be much less).

There are large opportunities for cost-effective energy savings in the future, which should allow these past trends to continue or even be accelerated. LBNL found the potential for about 25 quads of cumulative energy savings over the 2010–2030 period from new appliance and equipment efficiency standards, which works out to about 1.7 quads per year of savings once the equipment stock has turned over. In this paper we show how the LBNL estimates are likely conservative—we estimate a savings potential from new standards of at least 35 cumulative quads and perhaps as much as 48 quads. The latter works out to about 3.2 quads per year once the equipment stock turns over. LBNL also estimated more modest savings from building codes—about 5 quads of cumulative savings, which is about 0.5 quads per year in the out years. In this paper we do not estimate cumulative code savings but do estimate 0.94 quads in 2020, nearly twice the annual savings derived from the LBNL estimates.

Additional savings can be achieved with continued R&D efforts, continued utility-sector DSM programs, and other programs and policies. Quite a few studies indicate opportunities to achieve savings of 1.2–1.4% per year across multiple sectors over the next 20 or so years, in line with the recent historical experience for the buildings sector.

If these savings are achieved, they can exert downward pressure on energy prices and lead to modest improvements in the economy in addition to the more traditional benefits of energy efficiency such as direct energy bill savings, reduced emissions, reduced dependence on imported energy, and reduced need to develop energy sources in environmentally sensitive areas.

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