RAP Energy solutions for a changing world

Recognizing the Full Value of Energy Efficiency

(What's Under the Feel-Good Frosting of the World's Most Valuable Layer Cake of Benefits)

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September 2013

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Acronyms

ACI	Activated Carbon Injection
CCR	Coal Combustion Residuals
DR	Demand Response
DRIPE	Demand-Response Induced Price Effect
DSI	Dry Sorbent Injection
DTQ NEB	Difficult-to-Quantify Non-Energy Benefits
FGD	Flue Gas Desulfurization
GHG	Greenhouse Gas
IRP	Integrated Resource Planning
ISO-NE	ISO New England
LED	Light-Emitting Diode
LMP	Locational Marginal Price
NAAQS	National Ambient Air Quality Standards
NPV	Net Present Value
NO_X	Oxides of Nitrogen
O&M	Operations and Maintenance
PAC	Program Administrator Cost
PCT	Participant Cost Test
PG&E	Pacific Gas and Electric Company
$PM_{2.5}$	Fine Particle Emissions
RCRA	Resource Conservation and Recovery Act
RE	Renewable Energy
REC	Renewable Energy Certificate
RGGI	Regional Greenhouse Gas Initiative
RIM	Ratepayer Impact Measure (Test)
RPS	Renewable Portfolio Standard
SCR	Selective Catalytic Reduction
SCT	Societal Cost Test
SEEAction	State and Local Energy Efficiency Action Network
SIP	State Implementation Plan
SNCR	Selective Non-catalytic Reduction
SO_2	Sulfur Dioxide
TRC	Total Resource Cost (Test)
T&D	Transmission and Distribution
UCT	Utility Cost Test

Executive Summary

Energy efficiency provides numerous benefits to utilities, to participants (including rate payers), and to society as a whole. However, many of these benefits are frequently undervalued or not valued at all when energy efficiency measures are assessed. This paper seeks to comprehensively identify, characterize, and provide guidance regarding the quantification of the benefits provided by energy efficiency investments that save electricity. It focuses on the benefits of electric energy efficiency, but many of the same concepts are equally applicable to demand response (DR), renewable energy (RE), and water conservation measures. Similarly, they may also apply to efficiency investments associated with natural gas, fuel oil, or other end-user fuels.

This report is meant to provide a comprehensive guide to consideration and valuation (where possible) of energy efficiency benefits. It provides a real-world example that has accounted for many, but not all, of the energy efficiency benefits analyzed herein. We also provide a list of recommendations for regulators to consider when evaluating energy efficiency programs.

The energy efficiency benefits covered in this paper generally fall into three categories, echoed in the structure of this paper:[1]

- Benefits that accrue to the electric utility system;
- Benefits that accrue directly to the participating individual homes and businesses that install energy efficiency improvements (or may accrue to other utility systems serving them); and
- Benefits that accrue more broadly to society – the community, the region, the nation, or the planet – rather than to a specific consumer or utility system.

Because energy efficiency benefits vary so greatly in number and character, we have elected to describe these benefits as the layers in a cake. Thus, this paper will guide the reader through the layer cake of energy efficiency benefits.

After a brief review of the history and drivers of energy efficiency programs in Section 2, and a description of the various cost-benefit tests employed among various U.S. jurisdictions, the paper examines the layers of energy efficiency benefits in detail. The energy efficiency benefits examined herein include:

Benefits to the Utility

1. Production capacity cost savings
2. Production energy cost savings
3. Avoided costs of compliance with existing environmental regulations
4. Avoided costs of compliance with future environmental regulations
5. Transmission capacity cost savings
6. Distribution capacity savings
7. Avoided line losses
8. Minimizing reserve requirements
9. Decreased risk
10. Displacement of renewable resource obligations
11. Reduced credit and collection costs
12. Demand-Response Induced Price Effect (DRIPE)
13. Other utility benefits

Benefits to Participants

14. Reduced future energy bills
15. Operation and maintenance cost savings
16. Participant health impacts
17. Increased employee productivity
18. Effect on property values
19. Improved comfort

1 Structuring benefits into utility, participant, and societal categories is widely employed in evaluating energy efficiency programs and measures. See, for example, State and Local Energy Efficiency Action Network's (SEEAction) *Energy Efficiency Program Impact Evaluation Guide*, Section 7.9. Evaluation, Measurement, and Verification Working Group, 2012.

Table ES-1

Components of Energy Efficiency Cost-Effectiveness Tests

Benefit (or Cost)	Refer to Section	Participant Test	RIM Test	PAC Test	TRC Test	Societal Cost Test
Energy Efficiency Program Costs	3					
Program Administration Costs (including EM&V)	3.1	-	X	X	X	X
EE Measure Costs: Program Incentives	3.1	-	X	X	X	X
EE Measure Costs: Participant Contribution	3.1	X	-	-	X	X
EE Measure Costs: Third-Party Contribution	3.1	-	-	-	X	X
Other EE Costs	3.1	X	-	X	X	X
Lost Revenues to the Utility		-	X	-	-	-
Utility System Benefits	4					
Avoided Production Capacity Costs	4.3.1.1	-	X	X	X	X
Avoided Production Energy Costs	4.3.1.2	-	X	X	X	X
Avoided Costs of Existing Environmental Regulations	4.3.1.3	-	X	X	X	X
Avoided Costs of Future Environmental Regulations	4.3.1.4	-	X	X	X	X
Avoided Transmission Capacity Costs	4.3.1.5	-	X	X	X	X
Avoided Distribution Capacity Costs	4.4	-	X	X	X	X
Avoided Line Losses	4.5	-	X	X	X	X
Avoided Reserves	4.6	-	X	X	X	X
Avoided Risk	4.7	-	X	X	X	X
Displacement of Renewable Resource Obligation	4.8	-	X	X	X	X
Reduced Credit and Collection Costs	4.9	-	X	X	X	X
Demand-Response Induced Price Effect (DRIPE)	4.10	-	X	X	X	X
Other	4.11	-	-	-	-	See Text
Benefits To Participants	5					
Other Utility Benefits to Participants	5.1	X	-	-	X	X
Other Energy Savings (fuel oil, propane, natural gas)	5.2	X	-	-	X	X
Reduced Future Energy Bills	5.3	X	-	-	-	-
Other Resource Savings (septic, well pumping, etc.)	5.4	X	-	-	X	X
Non-Energy Benefits To Participants	6					
O&M Cost Savings	6.1	X	-	-	X	X
Participant Health Impacts	6.2	X	-	-	X	X
Employee Productivity	6.3	X	-	-	X	X
Property Values	6.4	X	-	-	See Text	-
Benefits Unique to Low-Income Consumers	6.5	X	-	-	-	X
Comfort	6.6	X	-	-	X	X
Other	6.7	X	-	-	X	X
Societal Non-Energy Benefits	7					
Air Quality Impacts	7.1.1	-	-	-	-	X
Water Quantity and Quality Impacts	7.1.2	-	X	X	X	X
Coal Ash Ponds and Coal Combustion Residuals	7.1.3	-	-	-	-	X
Employment Impacts	7.2.1	-	-	-	-	X
Economic Development	7.2.2	-	-	-	-	X
Other Economic Considerations	7.2.3		X	X	X	X
Societal Risk and Energy Security	7.3	-	-	-	-	X
Reduction of Effects of Termination of Service	7.4.1	-	X	X	X	X
Avoidance of Uncollectible Bills for Utilities	7.4.2	-	X	X	X	X
Electricity/Water Nexus	8					

Benefits to Society

20. Public health and welfare benefits
21. Air quality impacts
22. Water quality and quantity impacts
23. Decrease in coal ash ponds and coal combustion residuals
24. Improved economic development and employment effects
25. Decreased societal risk and increased energy security
26. Benefits for low-income customers

All of these benefits are explained in greater detail in the paper. A chart of the respective benefits, and how these benefits are treated under the five principle cost-effectiveness tests is shown in Table 1.

Full valuation of energy efficiency benefits begins with measurement of benefits and costs, and continues with detailed economic evaluation of the complete effects. To guide regulators, advocates, and analysts, we encourage participants to follow best practices, including:

- **Make sure you've accounted for everything you can quantify.** Analysis should at least list all costs and benefits borne by all parties when an energy efficiency measure is installed. This includes utility system benefits, benefits to participants, and benefits to society. It should include all identifiable energy and non-energy benefits, including health impacts avoided (or created) with energy efficiency measures.
- **Make the Societal Cost Test (SCT) the "threshold" test for measure inclusion in efficiency programs.** Measures that save more than they cost should be considered cost-effective, and included in programs where they are the best option for achieving those savings. Measures that cost more than they are worth should be treated very skeptically, unless there are research, development, or demonstration benefits.
- **Use the Program Administrator Cost (PAC) Test only as the basis for determining utility system contributions for programs made up of cost-effective measures identified through SCT or Total Resource Cost (TRC) test screening.** The utility system should not pay more for a program implementing cost-effective measures than the utility system benefit provided by that program. Where cost-effective measures with very significant non-utility benefits require additional funding to become generally accepted and implemented, then participants, government, or other beneficiaries should be sought as partners to provide the remaining funds.
- **Where measures pass the test with easy-to-count benefits, quit counting.** If measures are clearly justified on an energy-cost-only basis, it is not necessary to expend effort to identify additional benefits unless the opportunity exists to enlist program partners (like water and sewer utilities) in the funding mechanism.
- **Bundle measures with caution.** Sometimes it is appropriate to "bundle" some less cost-effective measures that can be logically implemented as a part of an overall program. An example is residential window replacements, which can enhance participation in residential insulation programs.[2] If the individual measures meet cost-effectiveness thresholds without consideration of administrative costs, and they attract additional program participants, it may be appropriate to bundle them with other measures in considering the portfolio's overall cost-effectiveness.
- **Judgment is important.** Where measures do not pass TRC and SCT on easy-to-quantify benefits, identify and list unquantified benefits. If they seem significant, use them as a guide for judgment on the part of the regulator and program administrator. As with other regulatory issues, ultimately the judgment of the regulator is critical to success.
- **Use a discount rate appropriate to the funding or benefitting entity.** The utility cost of capital is normally NOT an appropriate discount rate, because the funds are typically provided by customers through a system benefit charge. Therefore, it is more appropriate to apply a much lower societal discount rate for ratepayer-supported costs and for utility system and societal benefits. The use of a private discount rate may be appropriate only for private-supported costs and private benefits.
- **Use partners and advocates to help obtain data.** Utilities should use all available data on measure savings; energy efficiency vendors and advocates should be

2 For example, some utility residential programs have found that consumers assign very high value to energy-efficient windows, and have bundled these with inexpensive insulation measures in order to develop a package that is both cost-effective and attractive for consumers to participate.

expected to take an active role in helping to supply this data.

- **Use partners to help encourage participation.** Vendors, water, sewer, and natural gas utilities, low-income assistance programs, and other program co-sponsors can help with both marketing and funding. The health benefits of energy efficiency programs are becoming more widely recognized, and co-funding is an opportunity.
- **Use location-specific analysis.** In locations where transmission or distribution upgrades are needed, the transmission and distribution (T&D) benefits may be much higher than average. A location-specific analysis may elevate the cost-effectiveness of targeted measures, and may enable a deferral of upgrades.
- **Ensure that an adequate process for evaluation, measurement, and verification is in place.** Make sure that you follow up all programs with appropriate analysis to ensure that the expected benefits are being achieved.

Over the long term, society will pay higher costs whenever it pursues inefficient utilization of resources. Least-cost solutions almost always include energy efficiency. Incorporating energy efficiency reduces costs, impacts, and risks, and the sound use of energy is promoted. In short, conscious, concerted consideration of all energy efficiency benefits in regulatory decision-making enhances the potential for more optimal economic, social, and environmental outcomes.

PART I. Overview and Best Practices

1. Introduction and Overview

Enhancing the efficient use of electric energy provides a broad array of benefits. Some – like the avoided cost of energy – are obvious; others are obscure. Some have direct impacts on the electric power system; the impact of others occurs wholly outside the industry. Some can be readily monetized; others are almost impossible to quantify in economic terms. Some accrue to those who foot the bill; others inure to broader segments of society. Furthermore, because of differing perspectives, what may be seen as a benefit by one party (e.g., ratepayers paying for fewer kWh) may be seen as harmful by another (e.g., a utility absent decoupling, or a generator).

Historically, regulators evaluating the adoption or performance of energy efficiency measures have pursued a conservative path. They have considered, exclusively or primarily, only those benefits that are energy-related (and thus demonstrably within regulators' purview) and can be readily monetized. Other benefits have been regarded as "externalities" – external to power system considerations – and typically not considered, despite clear evidence of the magnitude of these benefits to society. There is also a need for clear quantification of the expected and potential magnitude of costs to the utility system as new air, water, solid waste, reliability, and other regulations are promulgated.

Studies suggest, however, that the non-energy benefits of efficiency measures can be quite large, often equal to or greater than the energy benefits. If so, then excluding them from regulatory consideration enhances the potential for suboptimal economic, social, and environmental outcomes.

This paper seeks to comprehensively identify, characterize, and provide guidance regarding the quantification of the benefits provided by energy efficiency investments that save electricity. It focuses on the benefits of electric energy efficiency, but many of the same concepts are equally applicable to demand response (DR), renewable energy (RE), and water conservation measures. Similarly, they may also apply to efficiency investments associated with natural gas, fuel oil, or other end-user fuels.

The benefits we cover generally fall into three categories, echoed in the structure of this paper:[3]

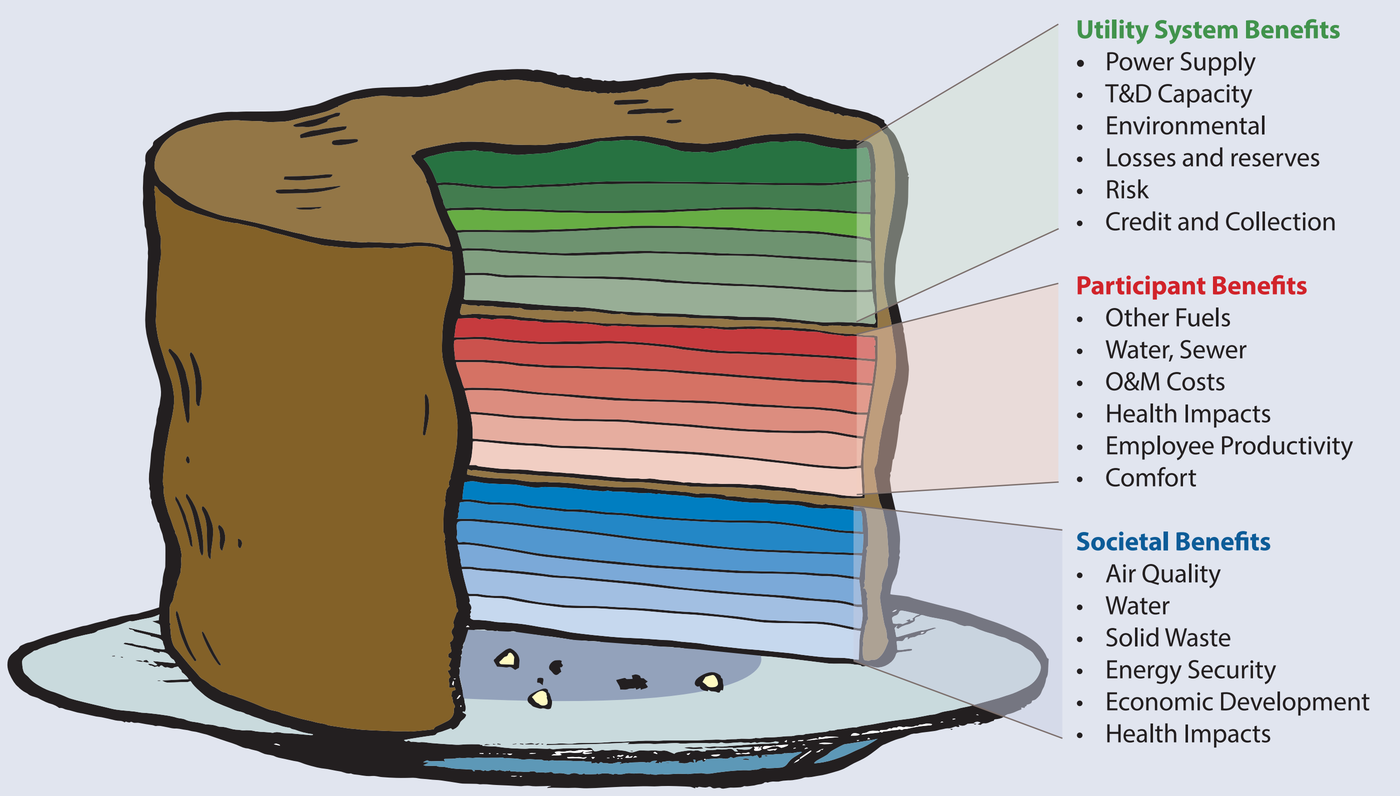
- Benefits that accrue to the electric utility system (Section 3);
- Benefits that accrue directly to the participating individual homes and businesses that install energy efficiency improvements (or may accrue to other utility systems serving them) (Sections 4 and 5); and
- Benefits that accrue more broadly to society – the community, the region, the nation, or the planet – rather than to a specific consumer or utility system (Sections 6 and 7).

> **"When Kiemle Hagood Company asked Avista Utilities how to save on its energy bill at one of its retail lease properties, the historic Flour Mill in Spokane, we partnered with them and found ways to increase efficiency and reduce energy use. Together, we also greatly reduced labor for repairs by increasing – and in some cases even doubling – the lifespan of equipment."**
> Avista Utilities Advertisement, *Alaska Airlines Magazine*, June 2013

3 Structuring benefits into utility, participant, and societal categories is widely employed in evaluating energy efficiency programs and measures. See, for example, State and Local Energy Efficiency Action Network's (SEEAction) *Energy Efficiency Program Impact Evaluation Guide,* Section 7.9. Evaluation, Measurement, and Verification Working Group, 2012.

Figure 1

A "Layer Cake" of Benefits from Electric Energy Efficiency

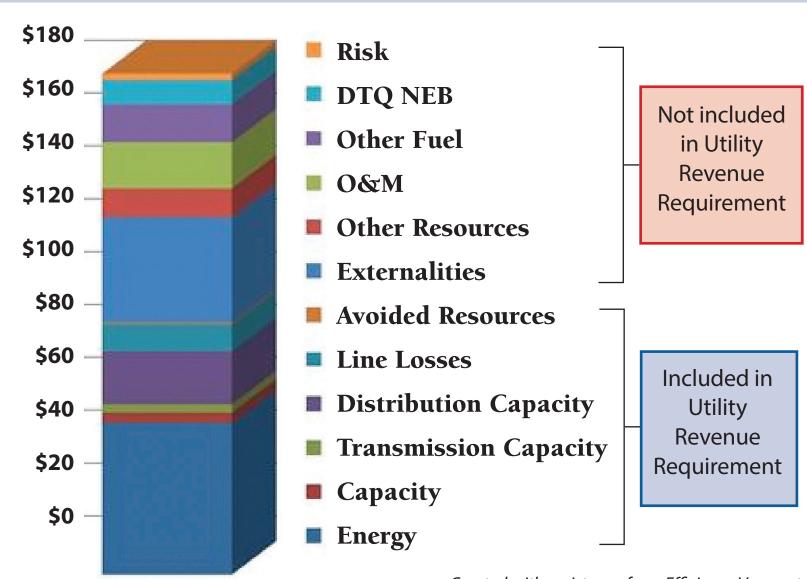


Even within this three-category framework, however, the number and character of efficiency benefits varies so greatly that we employ a readily recognizable artifact to differentiate and illuminate this variety: a "layer cake." Each distinct efficiency benefit can be characterized as a separate "layer," its thickness (where known) corresponding to the economic value it provides. In some instances, multiple distinct benefits have been aggregated into one layer for convenience of illustration. Where monetization is impossible, a default or "best estimate" regarding the layer's thickness has been used. Applied transparently, however, this "layer cake" image provides value: the cumulative height of the stack of layers illuminates the total estimated value of the combined benefits of energy efficiency – a value that may be helpful for public officials to keep in mind in reaching policy and regulatory decisions.

Figure 2

Vermont Energy Efficiency Savings Value

Updated Externality and NEB Values, $/MWh



Created with assistance from Efficiency Vermont, based upon data from their annual reports and personal communications.

One advantage of identifying multiple benefits of energy efficiency is that multiple partners can be sought and employed in support of energy efficiency programs. Where utility regulators, air regulators, economic development agencies, low-income assistance agencies, health agencies, and others work together, it may be possible to achieve much higher levels of savings. If water, sewer, natural gas, and solid waste utilities can be added as partners, additional funding for energy efficiency may be obtained. Sometimes these other utilities are regulated by the same entity regulating electric utilities, but often it will require intergovernmental cooperation to encourage water and sewer utilities, in particular, to participate in efficiency program funding.

To facilitate more accurate consideration of energy efficiency's cost-effectiveness in regulatory proceedings, we seek to identify and describe efficiency's numerous benefits and provide guidance on how these benefits can be analyzed and credited. Where available, examples are also provided to improve understanding of the analytical concepts. It is important to note, however, that benefits from electric energy efficiency vary greatly from place to place, owing to regional cost differences, seasonal energy consumption differences, the need for local T&D upgrades, and other factors. In addition, evaluations of energy efficiency benefits sometimes inadvertently double-count benefits; care should be taken to avoid this. Accordingly, state and local efficiency program administrators, regulators, policymakers, advocates, and vendors[4] should strive to ensure that quality data suitable to their jurisdiction is available and that appropriate assumptions are applied in these deliberations.

Before discussing the three general categories of efficiency benefits and associated specific benefits or individual "layers" in detail, it may be useful to briefly review the history, drivers, and cost-effectiveness tests behind today's energy efficiency and conservation programs.

4 Vendors such as appliance manufacturers, window vendors, and lighting manufacturers are perhaps in the best position to provide such data for their products.

2. Energy Conservation Programs: History and Drivers

Electric energy efficiency programs provided by U.S. utilities have their roots back in the 1970s, during the time of national energy crises and the subsequent focus on energy conservation and technological improvements in energy-using devices. By the late-1970s, a few utilities had established customer energy efficiency programs, including Pacific Gas & Electric in California, Pacific Power and Light in the northwest, and Portland General Electric in Oregon.[5] During the mid- to late-1980s, utility-sponsored electric energy efficiency programs grew rapidly, often as part of demand-side management practices.

The application of demand-side management reflected an important shift among utilities; many started to view demand as a resource that could be influenced and managed within their portfolios. The contemporaneous development of integrated resource planning (IRP) also began to treat energy efficiency as a resource on par with supply resources in a growing number of states. The Pacific Northwest Electric Power Planning and Conservation Act,[6] enacted by Congress in 1980, defined "cost-effective" to include a broad range of relevant costs, including "quantifiable environmental costs," and it assigned a 10-percent cost advantage to energy conservation measures in recognition of their advantages over supply-side options.[7] By the mid-1980s, utility conservation programs had emerged in New England, and by 1990, across the country.

Research conducted in 1989 gathered data for more than 200 commercial and industrial conservation and load management programs at 58 utilities throughout the United States, illustrating that energy efficiency programs were widespread at that time.[8] By 1993, utility spending on energy efficiency programs had risen to nearly $2 billion. Starting in the mid-1990s, however, utility spending on energy efficiency declined because of uncertainty about cost recovery and concerns about lost distribution margins amidst efforts to restructure and deregulate electricity markets. By 1998, program spending had fallen by approximately half its 1993 level.[9] Electric energy efficiency programs gradually rebounded from this low, increasing more quickly in the mid- to late-2000s and reaching $5.7 billion by 2011.[10]

As energy efficiency programs grew in the 1970s and 1980s, the need arose for cost-effectiveness tests to allow regulators to screen and evaluate energy efficiency programs. California paved the way in 1974 by creating the California Energy Commission and specifying cost-effectiveness as a primary resource planning principle.[11] Policymakers started to require cost-effectiveness as a condition of approval for energy efficiency initiatives. Early cost-effectiveness tests were fairly simple. For example, prior to 1982 most utilities in the northwest used the "no losers" test, which required that utilities not subsidize conservation programs whose cost exceeded the difference between average electric rates and the marginal cost of new resources.[12]

In 1983, California published its "Standard Practice for Cost-Benefit Analysis of Conservation and Load Management Programs" manual, laying out five cost-

5 ACEEE, 2012b.

6 Integrated resource planning in the United States began with passage of the Pacific Northwest Electric Power Planning and Conservation Act (PL 96-501).

7 16 USC 839(a).

8 ACEEE, 1990.

9 ACEEE, 2012b.

10 Consortium for Energy Efficiency, 2013.

11 NAPEE, 2008.

12 Peoples Organization for Washington Energy Resources, 1982.

effectiveness tests for evaluating energy efficiency programs. These five tests became widely used. The tests, now known as the Participant Cost Test (PCT), the Ratepayer Impact Measure (RIM) Test, the Program Administrator Cost Test (PAC), the Total Resource Cost (TRC) Test, and the Societal Cost Test (SCT), consider efficiency costs and benefits from different perspectives.[13] By 1992, at least eight states were using the RIM Test, while other states had rejected the RIM Test or relegated it to an informational role. At least seven states were using the TRC Test, and four of those relied on it exclusively; and three states were using the SCT.[14]

California's "Standard Practice Manual," as it became known, was updated twice, in 1988 and 2001, but the definitions of the tests did not change materially.[15] Even today, the five tests in the manual are still the primary methods that regulators use for determining the cost-effectiveness of energy efficiency programs. Overall, there has been increasing focus on the TRC Test since the first energy efficiency programs, but in many states little has changed over the years in the way the tests are applied.[16] By 2011, 36 states used the TRC test, with 29 of those using it as their primary test. Many states consider one or more other tests as well, but only 12 consider a non-TRC test as their primary cost-effectiveness test (RIM Test, one state; PAC Test, five states; SCT, six states).[17]

The emergence of the TRC Test as the predominant test represents an evolution toward recognizing more of the benefits of energy efficiency in cost-effectiveness analyses. The RIM Test and PAC Test include only the utility's energy-related and capacity-related avoided costs on the benefit side of the analysis. The TRC Test, when fully applied, expands the set of net benefits considered to include not only avoided costs, but also other resource savings such as gas and water savings, monetized non-energy benefits to participants, and applicable tax credits.[18] The SCT goes further, adding consideration of both monetized and non-monetized benefits to society, such as cleaner air and improved health. Several states with the best performing energy efficiency programs now use the SCT as their principal test.

Although the TRC Test is the most widely used test today, states commonly and incorrectly apply it without incorporating many energy efficiency benefits, including associated natural gas and water resource savings and monetized environmental and non-energy benefits. Costs, on the other hand, are completely applied. In 2011, only 12 of the 36 states using the TRC Test incorporated any type of non-energy benefits to participants. And most of those 12 states included only water and other fuel savings.[19]

Not surprisingly, incorporating non-energy benefits into cost-effectiveness tests can be difficult and has sometimes proven controversial. Some regulators and stakeholders resist including benefits like improved participant/public health, comfort, and property values because they are "externalities" outside the usual realm of utility regulation. In addition, estimating the value of some non-energy benefits can be complicated, leading many to resist any attempt at monetizing them. Most states that currently account for non-energy benefits typically do so only for benefits that are readily quantifiable.

There are exceptions, however. Regulators in Massachusetts have encouraged utilities to conduct studies of non-energy benefits and to include their values in cost-effectiveness tests for the last decade.[20] In another example, federal law requires the Bonneville Power Administration to account for all "quantifiable environmental costs" in evaluating generating resources, and to add a 10-percent premium in valuing energy efficiency.[21]

Many studies suggest that the non-energy benefits of efficiency measures are quite large. In fact, several studies

13 These cost-effectiveness tests are described in additional detail in Section 3.

14 U.S. Congress, Office of Technology Assessment, 1993.

15 California Public Utilities Commission, 2001.

16 Neme & Kushler, 2010.

17 ACEEE, 2012a.

18 The Standard Practice Manual indicates that these non-energy benefits are "adders" to the basic TRC calculation (p. 21); consistent with the term "Total Resource" this paper interprets the TRC test to include all resource-related costs and benefits that accrue within the utility service area, but not to include environmental externalities that are regional, national, or global in nature; these are specifically captured in the SCT.

19 ACEEE, 2012a.

20 Neme & Kushler, 2010.

21 16 USC 839(a). This language was substituted in place of the more vague phrasing "quantifiable social costs" during the drafting of the Northwest Power Act.

estimate the value of non-energy benefits at 50 to 100 percent, or more, of the energy benefits themselves.[22,23] Because these benefits are so large, failing to include them in the TRC and SCT can bias regulatory decisions against cost-effective efficiency investments – to the detriment of our economy and society. Notwithstanding the importance and value of identifying and quantifying non-energy benefits, there should be no expectation that the electric utility conservation program should provide funding in excess of the benefits that accrue to the utility system. Even utility system benefits, however, are routinely understated.

As a practical matter, using the TRC or SCT without full consideration of non-energy benefits creates a bias against energy efficiency in favor of supply, leading to greater costs to society over time.[24] The purpose of this paper is to comprehensively identify, characterize, and in some cases quantify the multiple benefits provided by energy efficiency in order to help regulators avoid undervaluing energy efficiency. In this manner, scarce funds, provided by electric bill payers, can be directed at the programs and measures that provide the greatest total benefit relative to the investment made.

Note that although this paper addresses non-energy benefits related to electric energy efficiency, many of the same concepts apply to natural gas energy efficiency programs, as well as programs relating to water and other resources. These efficiency programs may also have a wide range of utility, participant, and societal non-energy (or non-water) benefits that can be recognized by regulators within and/or alongside relevant cost-effectiveness tests in reaching program adoption and evaluation decisions.

22 Neme & Kushler, 2010.

23 Skumatz, 2006.

24 Eckman, 2011.

3. Measuring Benefits and Costs

Jurisdictions in the United States that have implemented ratepayer-funded efficiency programs typically require that these programs and measures pass one or several cost-effectiveness tests. Different cost tests consider costs and benefits from differing perspectives (e.g., the utility system, program participants, or society as a whole).[25] The breadth of the factors considered also varies among the tests and can further vary depending on the willingness of the jurisdiction to pursue a comprehensive assessment of the benefits of energy efficiency. This is particularly true of regarding estimates of non-energy benefits. The most common tests are briefly described below and in Table 1.

- **The Program Administrator Cost Test (PAC) – also called the Utility Cost Test (UCT) –** looks at costs and benefits from the perspective of the utility's revenue requirement. It seeks to answer the question of whether the utility's revenue requirements will decrease as a result of the program. The PAC test may result in acquisition of energy efficiency measures that do not, in the aggregate, save more than they cost. This can occur because of double-counting of benefits, if the utility's reduced power costs in offering an incentive are counted as a benefit under the UCT, and the participant's bill reductions (including power cost savings) in accepting the incentive and paying the balance of the measure cost under the PCT are counted as a benefit as well. These benefits are largely overlapping. This problem with the PAC has led to regulatory intervention to prevent utility investment in measures that are not cost-effective.[26]
- **The Total Resource Cost Test** is intended to include all costs and all benefits incurred by all customers (participants as well as non-participants) of the utility. It seeks to answer the question of whether the total

25 For a fuller discussion of the quantification of non-energy benefits (also known as Other Program Impacts), see Woolf et al, 2012.

26 Washington Utilities and Transportation Commission v. Puget Sound Power and Light Company, Docket No. 920630.

Misuse of the PAC Test: Funding Measures That Are Not Cost-Effective

A Pacific Northwest utility offered incentives for electric heat pump conversions in mobile homes from 1988 to 1990. At that time, the Company's avoided cost was reported at approximately $0.07/kWh, about the same as the end block of the inclining-block retail rate.

The incentives the utility offered worked out to approximately $0.06/kWh for the difference between electric resistance space heat and electric heat pump annual usage, so below the avoided cost, and therefore compliant with the PAC test. On a total resource cost basis, the cost of the heat pumps worked out to more like $0.12/kWh, well above the approved avoided cost.

The utility arranged with a third-party lender for loans for the balance of the cost, so customers did not have to bear any initial capital costs. The loan payments were structured to be smaller than the bill savings. The program was attractive to consumers, even though the heat pumps were not cost-effective, because the consumers paid for only half of the measure cost, and enjoyed savings immediately.

The utility carefully marketed this program ONLY to mobile home parks where their competitor gas utility was planning to install gas distribution systems. The result was that once the customers had accepted the heat pump loans, they tended to retain their electric water heaters, and the utility had succeeded in using a "conservation program" as a load-retention program.

Misuse of the PAC Test: Not Funding Measures That *Are* Cost-Effective

A southern U.S. electric utility is before its regulator for review of an updated integrated resource plan. In developing the Plan, this utility first “screened” measures using the TRC, but then determined how large a program to operate based on the PAC test.

The utility estimated that if they paid 25 percent of measure cost, they could get approximately one-third of the cost-effective conservation implemented. In order to increase this to two-thirds of the cost-effective conservation, they would have to offer incentives of 50 percent of measure cost. This is consistent with experience in other regions.

The utility then computed the INCREMENTAL amount of incentive payments required, and the INCREMENTAL amount of efficiency that would be achieved with the more aggressive incentives. The quotient of that calculation exceeded the avoided cost, and the utility has proposed only the lower level of incentives and thus achievement of only approximately one-third of available efficiency that meets the TRC test criteria.

In essence, the marginal UTILITY cost exceeded the utility avoided cost, but this calculation ignores the fact that with the more aggressive incentive, the customer payment would be correspondingly lower. From a TRC perspective, the more aggressive payment levels would generate an increase in the level of cost-effective conservation installed, an increase in incentives offset by a decrease in customer payments, and an increase in the net present value of benefits over costs. There was no suggestion that increasing the incentive would affect the installed cost of measures – it was strictly a PAC-based decision, looking at the incremental incentives and incremental savings from a utility revenue requirement perspective.

costs for all customers of the utility will decrease. This test includes the full costs of the measure, program administrative costs, and the benefits the measure provides, including operations and maintenance (O&M) savings, increased productivity, lowered absenteeism, and other non-energy benefits. Although most states specify the TRC test as the principal means for determining cost-effectiveness, very few actually require that all benefits accruing outside the utility system be quantified; this has led to severe underestimation of the benefit-to-cost ratio of energy efficiency measures under this test. It is crucial that analysts and regulators take full account of resource-related non-energy benefits in applying the TRC. Where these benefits cannot be easily quantified, the use of placeholders or default values may be

Misuse of the TRC Test: Omitting All Non-Energy Benefits

A natural gas utility has operated energy efficiency measures for many years, based on a TRC cost-effectiveness methodology. In response to sharply lower natural gas prices, the utility proposed to terminate its programs, because they were not cost-effective.

A conservation advocate proposed that the utility instead apply a PAC test to their conservation program, paying up to, but not exceeding, the newly lower avoided cost for energy efficiency measures, ignoring customer payments.

Upon examination, the regulator found that the utility had not included any non-energy benefits in the TRC calculation. No provision was made for CO_2 emissions from the retail consumption, or for CO_2 emissions in the upstream gas production, treatment, and compression. No calculation was performed for customer comfort, moisture and mold reduction, or noise attenuation. Indeed, no value was assigned to the reduction of transmission peak demand, distribution peak demand, marginal losses, or reserves.

Essentially the regulator found that the proposal to terminate the programs was based on a flawed application of the TRC. Properly applied, the gas conservation measures were cost-effective under the previously approved TRC. There was no need to consider the request to apply a PAC test-based criteria instead.

necessary; otherwise, the value of these benefits is carried as zero, which is almost certainly the wrong number.

- **The Societal Cost Test** includes all costs and benefits experienced by society as a whole. It seeks to answer the question of whether society is better off with the program. It includes all of the TRC costs and benefits, plus the full costs of environmental and other externalities. This cost would be netted against any portion of environmental costs that have already been internalized (e.g., through the purchase of emissions allowances or other means).

Finally, there are two tests that are seldom used by utility regulators but which do provide important information.

- **The Participant Cost Test** looks at costs and benefits from the perspective of the program participant. This test assesses the willingness of a customer to install a measure when presented with the terms of the energy efficiency program, so it is used mostly for program design purposes.
- **The Ratepayer Impact Measure Test** includes only those costs and benefits that affect utility rates. This test examines the impact of utility-sponsored energy efficiency programs upon the rates of non-participants. Very few, if any, states use the RIM test as the primary determinant of cost-effectiveness for their energy efficiency programs, in part because it can easily foster counterproductive outcomes.[27] This test asks the question of whether utility rates will decrease upon implementation of a program, rather than looking at the program's costs or the value of the benefits it provides. Inclusion of revenue lost to the utility as a result of program activity in the cost-effectiveness test can have a large impact on whether a measure or program passes the screening. This test is sometimes called the "No-Losers" test. Although almost no utility regulators use this as a screening test, many regulators are appropriately concerned about the magnitude of rate impacts, and so do consider the results of the RIM test.

3.1. Energy Efficiency Costs

Implementing energy efficiency is not free, and although it is beyond the scope of this paper to detail its costs, it is important to note the categories of cost that should be considered in comparing energy efficiency costs to energy efficiency benefits. Typically some of these costs are borne by utilities (or third parties acting in association with utilities), some by participants, and some by others.

Utility costs include program administration (audits, measurement and verification, regulatory reporting, accounting and record-keeping, strategic marketing and database management, and the overhead associated with each of these), plus the actual incentives paid to assist consumers.[28]

Participant costs include the portion of measure costs paid by participants, plus the time and inconvenience borne by participants in order to facilitate measure installation, testing, and commissioning.

Third-party costs may include government financial assistance, low-income program staff time, or supplemental payments made by partners such as water, sewer, and natural gas utilities.

The treatment of tax benefits (such as sales tax exemptions for energy efficiency measures or investment tax credits) should be consistent with treatment of tax benefits for supply-side resources. For example, if the savings from the federal production tax credit for wind power is not included in the avoided cost of energy, then savings from tax benefits for energy efficiency measures should be similarly excluded from the cost calculation for efficiency.[29]

27 For example, a program to install less efficient air conditioners would increase electricity consumption, thereby reducing utility fixed costs per kWh and reducing overall rates as a result. Accordingly, such an energy inefficiency program would pass the RIM test.

28 Low utility costs could mean exceptional efficiency or it could mean inept efforts to sell energy efficiency. Simple comparison of administrative costs from program to program and utility to utility tells nothing without an assessment of the purpose and effectiveness of the program administrator's work.

29 In theory, the SCT should exclude all tax effects, because they are all transfer payments; in practice, it would probably be impossible to identify, quantify, and remove these from the cost of either supply or energy efficiency measures.

Table 1

Components of Energy Efficiency Cost-Effectiveness Tests

Benefit (or Cost)	Refer to Section	Participant Test	RIM Test	PAC Test	TRC Test	Societal Cost Test
Energy Efficiency Program Costs	3					
Program Administration Costs (including EM&V)	3.1	-	X	X	X	X
EE Measure Costs: Program Incentives	3.1	-	X	X	X	X
EE Measure Costs: Participant Contribution	3.1	X	-	-	X	X
EE Measure Costs: Third-Party Contribution	3.1	-	-	-	X	X
Other EE Costs	3.1	X	-	X	X	X
Lost Revenues to the Utility		-	X	-	-	-
Utility System Benefits	4					
Avoided Production Capacity Costs	4.3.1.1	-	X	X	X	X
Avoided Production Energy Costs	4.3.1.2	-	X	X	X	X
Avoided Costs of Existing Environmental Regulations	4.3.1.3	-	X	X	X	X
Avoided Costs of Future Environmental Regulations	4.3.1.4	-	X	X	X	X
Avoided Transmission Capacity Costs	4.3.1.5	-	X	X	X	X
Avoided Distribution Capacity Costs	4.4	-	X	X	X	X
Avoided Line Losses	4.5	-	X	X	X	X
Avoided Reserves	4.6	-	X	X	X	X
Avoided Risk	4.7	-	X	X	X	X
Displacement of Renewable Resource Obligation	4.8	-	X	X	X	X
Reduced Credit and Collection Costs	4.9	-	X	X	X	X
Demand-Response Induced Price Effect (DRIPE)	4.10	-	X	X	X	X
Other	4.11	-	-	-	-	See Text
Benefits To Participants	5					
Other Utility Benefits to Participants	5.1	X	-	-	X	X
Other Energy Savings (fuel oil, propane, natural gas)	5.2	X	-	-	X	X
Reduced Future Energy Bills	5.3	X	-	-	-	-
Other Resource Savings (septic, well pumping, etc.)	5.4	X	-	-	X	X
Non-Energy Benefits To Participants	6					
O&M Cost Savings	6.1	X	-	-	X	X
Participant Health Impacts	6.2	X	-	-	X	X
Employee Productivity	6.3	X	-	-	X	X
Property Values	6.4	X	-	-	See Text	-
Benefits Unique to Low-Income Consumers	6.5	X	-	-	-	X
Comfort	6.6	X	-	-	X	X
Other	6.7	X	-	-	X	X
Societal Non-Energy Benefits	7					
Air Quality Impacts	7.1.1	-	-	-	-	X
Water Quantity and Quality Impacts	7.1.2	-	X	X	X	X
Coal Ash Ponds and Coal Combustion Residuals	7.1.3	-	-	-	-	X
Employment Impacts	7.2.1	-	-	-	-	X
Economic Development	7.2.2	-	-	-	-	X
Other Economic Considerations	7.2.3		X	X	X	X
Societal Risk and Energy Security	7.3	-	-	-	-	X
Reduction of Effects of Termination of Service	7.4.1	-	X	X	X	X
Avoidance of Uncollectible Bills for Utilities	7.4.2	-	X	X	X	X
Electricity/Water Nexus	8					

3.2. How Energy Efficiency Benefits and Costs Fit Within Cost-Effectiveness Tests

Table 1 summarizes how the benefits and costs of energy efficiency programs should be incorporated into these common cost-effectiveness tests. The most common omissions are non-utility benefits in TRC calculations. This paper includes these benefits to be symmetrical with the treatment of costs – where non-utility costs are included, so are non-utility benefits.

3.3. Recommendations for Using Cost-Effectiveness Tests

There are multiple uses for cost-effectiveness tests. One purpose is screening, to determine which measures should be included in utility programs. Another purpose is identification of program partners, such as water and sewer utilities. A third purpose is determination of the appropriate incentive payments to enhance participation. A final purpose is for information on the breadth of impacts that will result from program operation.

About Discount Rates

Typically the bulk of the costs of an energy efficiency investment are incurred in the first year, while its benefits accrue over the life of the investment. Costs and benefits that occur over time are generally discounted to a common year in order to enable cost-effectiveness comparisons. The choice of a discount rate to use in this process can dramatically influence the results.

Discounting, and the choice of a discount rate, primarily reflects three influences on future cash flows. The first is inflation. Generally, a dollar in a future year will not have the same purchasing power as a dollar today. The second reason is preference in time. Most people would simply rather have a dollar today than a dollar tomorrow. The third influence reflects risk. Future cash flows or value are rarely guaranteed, and some investments have more risk than others.

Much like the cost-effectiveness tests themselves, the choice of a discount rate can reflect the preferences of the evaluating party. The Societal Cost Test should reflect the values of society, for instance, which should not only have access to capital at a lower cost, but also have a broader risk tolerance for receiving benefits in the future. The circumstances of different customer groups, notably at-risk and low-income populations, can also be reflected in the choice of a discount rate. Society is often supporting these customers in some way already, so it may be appropriate to use a societal discount rate (even in the context of the other tests) when analyzing investments applicable to these population cohorts. The societal test also includes environmental externality costs, which should be discounted at a low rate, if at all.

Historically, the TRC and the PAC tests have been used to compare efficiency investments with traditional supply-side investments, using the utility's net-of-tax weighted average cost of capital (WACC) to discount efficiency savings. However, over time, it has become apparent that there are significant differences in the financial risks posed by energy efficiency and supply-side investments. Energy efficiency is frequently funded by a system benefits charge, so there is little risk that the utility will not recover its costs and there is little time lag in their recovery. Their recovery is also independent of utility performance or other business risk factors. Also, even if estimates of savings or value from an EE measure or program are incorrect, the measure will return some benefits over its life, unlike an investment in a power plant that gets only partially built or one that is deemed uneconomic down the road. The discount rates chosen should reflect the actual risks inherent in these investments. Accordingly, a low discount rate – such as that of long-term U.S. Treasury Bills – may appropriately reflect the risk associated with EE programs.

In some situations, a discount rate of zero may be appropriate. If climate change is the overwhelming driver for energy efficiency programs in order to avoid marginal generation from fossil fuels, carbon saved tomorrow may be as important as carbon saved today. In this formulation, a discount rate of zero can be justified.

(For a more complete discussion of discount rate selection in energy efficiency programs, see: Woolf et al, 2012)

In determining the appropriate cost-effectiveness tests to apply, it is important to establish the desired goals for the energy efficiency programs. These goals can then inform which components of the "layer cake" are important to include in cost-effectiveness screening.

If the goal is to improve conditions for all of society, for example, then the most expansive test, the SCT, should be used. If one wants to confine consideration to only utility customers, then the TRC test should be applied, including those non-energy benefits that accrue to customers.[30] In some places, political realities focus attention on the pure "value for money" exchange of *utility* customer dollars collected to pay for programs that influence and avoid more expensive *utility* investments over time. The PAC test is appropriate for this instance. If the objectives are to focus on a smaller subset of individuals, then other tests should be considered tailored to the purpose. In all cases, the test used is most appropriate if it matches the public purpose for having energy efficiency programs funded by utility consumers in the first place. Where multiple purposes exist, multiple tests are likely to be useful.

In 2012, ACEEE surveyed states about their practices concerning implementation and evaluation of energy efficiency programs. Among states with active energy efficiency programs, this research determined that most consider several of the different cost-effectiveness tests in evaluating their programs. The overwhelming majority of states (71 percent), however, use the TRC test as their primary test. Six states (15 percent) employ the SCT, and five states (12 percent) rely on the PAC/UCT test. Only one state uses the RIM test as its primary cost-effectiveness test.

The SCT is the broadest in scope and most appropriate for those jurisdictions that want to pursue goals that include a wide range of benefits, including non-energy benefits like improvements in unpriced externalities. Critics often claim that the benefits considered in this test are outside the scope of what a regulated utility or its ratepayers should pursue. It is important, however, to distinguish between (1) the screening of programs or measures in order to determine which if any are optimal to pursue with public policy steps, and (2) the level of ratepayer funding that should be invested. Screening merely identifies which measures or programs are eligible to be included in a sanctioned program or portfolio. Program design strategies can dictate, however, that ratepayers should not pay more than what a measure or program is worth to ratepayers. So a measure that costs $100 and has $75 in utility benefits and $50 in other benefits would pass the screening, but would only be eligible for ratepayer funding up to $75. Thus, the fact that a measure may pass screening doesn't necessarily mean that per-unit savings costs experienced by the utility will rise.

Program design strategies can dictate, however, that ratepayers should not pay more than what a measure or program is worth to ratepayers.

In evaluating the cost-effectiveness of energy efficiency measures, the long-run marginal costs avoided by the utility, the consumer, and non-participants should always guide evaluation. Energy efficiency measures last a long time, and it is generally appropriate to compare these with new power supply, transmission, and distribution resources that are obviated by efficiency. Most utility cost allocation studies that quantify transmission and distribution costs do not look at long-run marginal costs, however, so the efficiency program analyst may need to do considerable research to develop good metrics, particularly for these savings elements.

3.4. Some Examples Where the Evaluation Approach Matters

Experience to date provides some excellent examples of how avoided utility costs, avoided participant costs, and avoided societal costs can be evaluated. A few illustrative examples are particularly useful.

New Zealand Low-Income Weatherization. Detailed evaluation of this program showed that energy benefits alone were insufficient to justify the expenditures, but that health benefits were much larger than the measured energy benefits. Although a TRC benefit-to-cost ratio did not exceed 1.0:1 on an energy-only basis, the societal benefit-to-cost ratio was approximately 4:1.[32]

30 Some analysts interpret the TRC test narrowly to include only utility-related benefits, while others incorporate all resource-related costs and benefits, including water, sewer, and labor resources. This paper adheres to the latter interpretation of TRC.

31 ACEEE, 2012a.

32 Grimes et al, 2012.

Horizontal-Axis Washing Machines. The incremental cost of high-efficiency washers was not justified by electricity savings alone, but when water, sewer, natural gas, and soap savings were considered, the benefit-to-cost ratio reached 2.8:1.[33]

Commercial Lighting. Although commercial lighting upgrades are often cost-effective on an energy-only basis, analysis shows that when non-energy benefits, such as employee productivity are considered, the benefit-to-cost ratio can sharply increase.

Industrial Process Improvements. Many industrial process improvements are justifiable on an energy-only basis, but when avoided air pollution costs and health impacts are included, the economics become far more robust.

3.5. Best Practice Recommendations

Full valuation of energy efficiency benefits begins with measurement of benefits and costs, and continues with detailed economic evaluation of the complete effects. To guide regulators, advocates, and analysts, we encourage participants to follow best practices, including:

- **Make sure you've accounted for everything you can quantify.** Analysis should at least list all costs and benefits borne by all parties when an energy efficiency measure is installed. This includes utility system benefits, benefits to participants, and benefits to society. It should include all identifiable energy and non-energy benefits, including health impacts avoided (or created) with energy efficiency measures.
- **Make the SCT the "threshold" test for measure inclusion in efficiency programs.** Measures that save more than they cost should be considered cost-effective and included in programs where they are the best option for achieving those savings. Measures that cost more than they are worth should be treated very skeptically, unless there are research, development, or demonstration benefits.
- **Use the PAC Test only as the basis for determining utility system contributions for programs made up of cost-effective measures identified through SCT or TRC screening.** The utility system should not pay more for a program implementing cost-effective measures than the utility system benefit provided by that program. Where cost-effective measures with very significant non-utility benefits require additional funding to become generally accepted and implemented, then participants, government, or other beneficiaries should be sought as partners to provide the remaining funds.
- **Where measures pass the test with easy-to-count benefits, quit counting.** If measures are clearly justified on an energy-cost-only basis, it is not necessary to expend effort to identify additional benefits unless the opportunity exists to enlist program partners (like water and sewer utilities) in the funding mechanism.
- **Bundle measures with caution.** Sometimes it is appropriate to "bundle" some less cost-effective measures that can be logically implemented as a part of an overall program. An example is residential window replacements, which can enhance participation in residential insulation programs.[34] If the individual measures meet cost-effectiveness thresholds without consideration of administrative costs, and they attract additional program participants, it may be appropriate to bundle them in considering the portfolio's overall cost-effectiveness.
- **Judgment is important.** Where measures do not pass TRC and SCT on easy-to-quantify benefits, identify and list unquantified benefits. If they seem significant, use them as a guide for judgment on the part of the regulator and program administrator. As with other regulatory issues, ultimately the judgment of the regulator is critical to success.
- **Use a discount rate appropriate to the funding or benefitting entity.** The utility cost of capital is normally NOT an appropriate discount rate, because the funds are typically provided by customers through a system benefit charge. Therefore, it is more appropriate to apply a much lower societal discount rate for ratepayer-supported costs and for utility system and societal benefits. The use of a private discount rate may be appropriate only for private-supported costs and private benefits.

33 Northwest Power and Conservation Council, 2010.

34 For example, some utility residential programs have found that consumers assign very high value to energy-efficient windows, and have bundled these with inexpensive insulation measures in order to develop a package that is both cost-effective and attractive for consumers to participate.

- **Use partners and advocates to help obtain data.** Utilities should use all available data on measure savings; energy efficiency vendors and advocates should be expected to take an active role in helping to supply this data.
- **Use partners to help encourage participation.** Vendors, water, sewer, and natural gas utilities, low-income assistance programs, and other program co-sponsors can help with both marketing and funding. The health benefits of energy efficiency programs are becoming more widely recognized, and co-funding is an opportunity.
- **Use location-specific analysis.** In locations where transmission or distribution upgrades are needed, the T&D benefits may be much higher than average. A location-specific analysis may elevate the cost-effectiveness of targeted measures and enable a deferral of upgrades.
- **Ensure that an adequate process for evaluation, measurement, and verification is in place.** Make sure that you follow up all programs with appropriate analysis to ensure that the expected benefits are being achieved.

3.6. An Actual Example of Utility Regulators' Comprehensive Measurements of the "Layer Cake" of Benefits

Actually measuring the benefits from energy efficiency and translating them into a cents-per-kWh value involves developing the estimated energy reduction benefits of a portfolio of energy efficiency measures, each with a specific lifetime and energy savings profile. To do this, measures' energy savings are segregated into "bins" representing winter/summer and peak/off peak energy reductions. Avoided costs are then calculated for each bin, based on output from a dispatch model.[35] The cost savings for each measure are then levelized over its lifetime and divided by the annual energy savings for the measure in order to derive the cents-per-kWh benefits of the measure.

For capital costs avoided by energy efficiency measures, avoided carrying costs (or market values) are used. For values that change over a measure's life, a levelized value is used. This levelized value is computed over the measure's overall lifetime.

The energy savings and their values presented below are taken from Efficiency Vermont's annual report for 2010,[36] reflecting energy efficiency activities completed in 2010. The energy savings are annualized, which means that for reporting and analysis purposes, all measures are assumed to have been in place on January 1st. The overall energy savings represent the reductions attributable to the specific mix of measures and projects that were completed in 2010 over the lifetime of each individual measure.

Energy efficiency is generally measured at the customer's meter, so some adjustments will be needed to reflect savings at the generator (e.g., reduced marginal line losses, which greatly exceed average line losses).

The descriptions of the "layers of the cake" as applied in this Vermont example are as follows:

Production energy cost savings reflect the weighted average avoided energy cost of the marginal generating units in each hour. It is the total energy dollar savings divided by the total MWh savings. So this is not exactly marginal cost, but a weighted average, based on the load shape of the energy reductions. The dollar savings value is derived from a market energy cost projection prepared every two years for the New England states.

On page two of its 2010 annual report, Efficiency Vermont reported an annualized energy savings of 110,800 MWh per year. The net present value (NPV) savings from this energy reduction was reported to be $49,027,000. This value was levelized over the average measure life of the measures installed in that year (10.4 years), yielding an annual value of $6,378,000. Dividing this by the annualized energy savings of 110,800 MWh yields a value of $57.54/MWh.

Production capacity cost savings are computed using the "equivalent peaker" approach discussed previously, as well as market data from ISO-New England (ISO-NE). It is the levelized annual capacity dollar savings divided by the annualized MWh savings.

The NPV savings calculated for reduced production capacity in Vermont in 2010 was $3,227,000. The dollar savings value was levelized over the average measure life of 10.4 years, yielding an annual value of $419,870. Dividing this by the annualized energy reductions yields a value of $3.79/MWh.

35 Hornby et al, 2009. An updated report is also available.

36 Efficiency Vermont, 2012.

In this Efficiency Vermont case, regulators assessed the value of avoided **transmission capacity costs** and avoided **distribution capacity costs** jointly, as **"T&D Capacity."** It reflects the value of being able to defer T&D expansion as a result of implementing energy efficiency measures. Essentially this is the carrying cost of any deferred T&D investments, levelized over the life of the efficiency measures and divided by the annualized MWh energy savings. It does not include any T&D maintenance expenses.

Efficiency Vermont reported an NPV savings from avoided generation and T&D capacity to be $23,562,000 (not including losses). These savings were parsed between generation capacity and T&D capacity based on typical screening values in the Vermont screening tool used to evaluate energy efficiency. Transmission and distribution are then separated using an average of the ratio of values reported by New England utilities.[37] The allocated T&D savings values were $2,728,000 and $17,037,000, respectively. These savings values were levelized and divided by the MWh savings to create T&D savings values of $3.20/MWh and $19.99/MWh, respectively.

Line losses are marginal losses, used to gross-up energy efficiency savings, because they are generally measured at the customer meter. This "layer" represents both energy and capacity (including T&D capacity) cost reductions attributable to reduced line losses as a result of energy savings from efficiency measures. The NPV total savings from reduced line losses was estimated to be $8,684,000. This was levelized over the average measure life to produce a value of $10.19/MWh.

Avoided **reserves** represent the savings in capacity reserves (generally in the 10- to 15-percent range) resulting from lower peak demands made possible by energy efficiency measures. Reserve capacity is required in order to cover unexpected or planned outages. If, for instance, the avoided load attributable to energy efficiency is 10 MW at the customer meter, and is adjusted up to 11.2 MW to include line losses, the need for the utility to purchase or maintain an additional 15 percent of that amount for reserve capacity is also avoided. In Vermont, the value of capacity reserves was assumed to be 15 percent of the total dollar value for avoided production energy capacity. This value was levelized over the measure life and divided by the annual energy savings to produce a value of $0.67/MWh.

In Vermont's assessment, **externalities** represent the dollar value of avoided stack emissions that are not internalized. The value was obtained from the Avoided Energy Supply Cost report referenced previously and is based almost exclusively on the estimated damage costs of CO_2 emissions. Additional stack emissions besides CO_2 are also avoided, as are other externalized costs of power production, but carbon emissions are the dominant element. Based on carbon damage costs of $20/ton, and internalized Regional Greenhouse Gas Initiative (RGGI) carbon mitigation costs of $2/ton, the value Vermont computed was $9.44/MWh. Vermont updated its carbon damage cost to $80/ton in 2012; with this change, the 2012 updated value for externalities increased to $39.98/MWh.

Other Resource Benefits to Participant and **Other Resource Savings** (called simply **"Other Resources"** in Vermont's assessment) represent savings – as well as costs where encountered – to the consumer, owing to changes in the use of other resources following implementation of energy efficiency measures. For example, an efficient clothes washer will use less water, not just less electricity. The NPV savings of other resources (mostly water) was estimated by Vermont to be $9,214,000. This was levelized over the energy savings and measures' lives to yield a value of $10.81/MWh.

O&M Cost Savings (labeled **"O&M"** in Vermont's case) represents operations and maintenance savings to the consumer from the installation of energy efficiency measures. For example, a light-emitting diode (LED) or compact fluorescent light bulb will avoid the purchase and replacement of several incandescent bulbs, in addition to the electric savings they provide. NPV savings from reduced O&M was estimated to be $14,845,000 in Vermont. This was levelized over the energy savings and measures' lives to yield a value of $17.42/MWh.

Other Energy Savings (called **"Other Fuel"** in the Vermont analysis) represents the net savings and costs of incremental fuel use resulting from energy efficiency measures. Insulating a building to reduce air conditioning needs, for example, will also save heating fuel. On the other hand, replacing incandescent bulbs will save electricity but – being cooler – will increase heating costs slightly. NPV savings of other fuels (net of any increases from lower internal gains) was estimated in Vermont to be

37 Hornby et al, 2011. Exhibit 6-45.

$12,291,000. This was levelized over the energy savings and measures' lives to yield a value of $14.42/MWh.

Vermont's assessment categorized as **"Difficult-to-Quantify Non-Energy Benefits (DTQ NEB)"** an array of other non-benefits that derive from energy efficiency, some of which can be readily measured, others of which cannot. This category includes greater comfort, improved health, enhanced productivity, and others. Lacking precise quantification, Vermont's evaluation used 15 percent of energy and capacity benefits as a placeholder assumption for the value of these non-energy benefits. There is considerable effort now underway to better understand and quantify these non-energy benefits.[38] Vermont's 15-percent assumption translates to $9.30/MWh.

Vermont also applied a 10-percent adjustment to the cost of energy efficiency measures to reflect the benefit of lower **risk** that they provide. Specifically, the cost of an energy efficiency measure is discounted (relative to traditional supply) to reflect the improved risk characteristics of energy efficiency – namely the ability to readily increase or decrease program activity to meet needs, the incremental nature of energy efficiency impacts, and the limited risk of stranded investment. This discounting makes the effective cost of energy efficiency lower, and is shown as a benefit. Vermont's total measure cost (i.e., participant costs plus program incentives) was $19,388,000. Levelized over the measures' lifetime, 10 percent of that sum is $2.27/MWh.

Total – Adding together all of the dollar values for energy efficiency benefits that Vermont calculated and/or assumed produces a total value of $149.74/MWh – nearly 15 cents per kWh. By comparison, the overall cost for efficiency measures delivered in Vermont in 2010 (i.e., program costs plus net participant costs plus incentives plus third party costs) was 4.0 cents/kWh. With the updated value for externalities adopted in 2012, the total value rose to $187.32/MWh – nearly 19 cents per kWh.

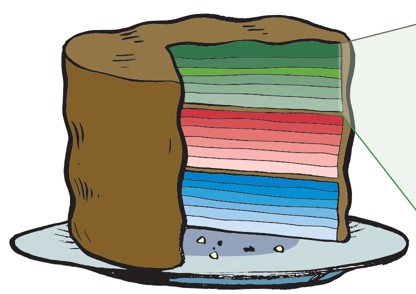
As impressive as this total value is, even it is not complete. Vermont did not explicitly consider several additional benefits described in this paper. These include, for example, displacement of renewable obligation,[39] reduced future energy bills, several environmental benefits, employment impacts, economic development constraints, demand-response induced price effects (DRIPE), energy security, and low-income impacts.

38 Efficiency Vermont, 2012. Page 3.

39 Vermont does not currently have a renewable portfolio standard or other minimum renewable energy standard for electric utilities.

PART II. Detailed Discussion of Energy Efficiency Benefits

4. Utility System Benefits



Energy efficiency benefits to the utility system include reductions in energy requirements and avoidance of production, transmission, and distribution capacity investments. In addition, line losses and reserves are avoided whenever end-uses become more efficient. Reduced credit and collection costs, reduced risk of many kinds, and lower market clearing prices for power and fuel as demand slides down the supply curve are important. Finally, pollutants emitted by power plants are avoided, as are water and other resources used by plants. All of these need to be considered because they too provide savings to the utility's cost of service in the near- or long-term.[40] This section looks at each of these types of benefits in turn.

We present actual figures from selected energy efficiency measures, and from specific utility cost studies. These figures are intended to be illustrative of the results that could be obtained from examination of energy efficiency measures in any jurisdiction, but local data should always be used to measure local benefits.

4.1. Measuring Capacity Benefits of Energy Efficiency

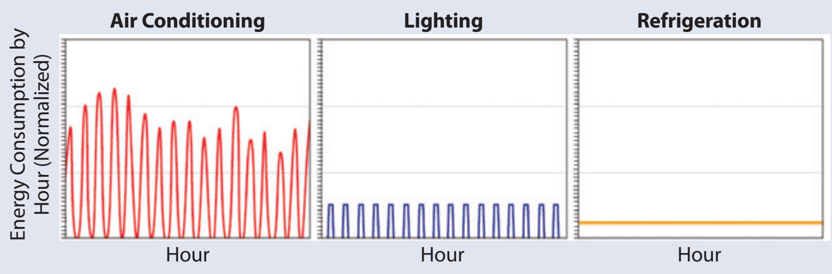
Most energy efficiency measures reduce peak demand. To value this benefit, one needs to know the "resource shape" of the energy efficiency measures at the generation, transmission, and distribution level relative to the system peak demands in those locations, and the incremental cost of augmenting that capacity.

Some energy efficiency measures are very peak-oriented, such as Energy Star® air conditioners, whereas others, like street lighting upgrades, provide primarily off-peak savings. In between are measures that save energy all day, like more efficient refrigerators. Those measures providing meaningful peak load reduction should be characterized and credited with appropriate production, transmission, and distribution capacity cost benefits.[41]

Figure 3 shows hourly resource shapes for three

Figure 3

Hourly Savings From Select Energy Efficiency Measures in California[42]



40 They also provide benefits to society as well; these are addressed separately in a later section.

41 A detailed discussion of the peak capacity issue may be found in York et al, 2007.

42 NAPEE, 2007. p. 7-7.

illustrative energy efficiency measures. When translated into capacity values, the results can be very different for different measures.

4.2. Economic Theory: Short-Run Versus Long-Run Marginal Costs

In economic theory, a market is in "equilibrium" if short-run marginal costs (the cost of generating an additional increment of output from existing facilities) are equal to long-run marginal costs (the cost of building and operating a new facility). This occurs, for example, when the cost of generating an additional kWh from existing facilities would involve using a relatively inefficient power plant with a commensurately high fuel cost, while the cost of building and operating a new plant would involve additional investment, but lower operating cost.

Utility systems and grids are seldom in equilibrium, in part because they are required to have reserve capacity to ensure reliable service, and the reserve capacity requirements tip utility systems out of equilibrium. During all hours when that reserve capacity is not needed, the system has excess capacity that can be operated based on variable fuel and maintenance expense only. As a result, looking at short-term "dispatch" or "market" costs tends to severely understate the long-run value of long-lived measures, including energy efficiency. It is important that a stream of benefits be calculated for a period of at least 20 years; a 30- to 40-year stream of benefits, comparable to the 30- to 40-year life of a power plant or transmission upgrade is better. If a long-run stream of avoided costs is used, the inclusion of a short-term surplus will have relatively little effect on the cost-effectiveness calculation. In Table 2, the 30-year avoided costs for New England, computed in 2009, are approximately 20 percent higher than the 10-year avoided costs.

For restructured regions with fully competitive power supply markets, a different approach is needed. The present value of forecast market clearing prices over the lifecycle of an efficiency measure is probably the most common way to "value" the energy benefits of that measure. It is more complex to value the capacity benefits in a restructured market, in part because a separate capacity market may not exist, and in part because transmission values may be bundled into nodal energy prices. This is not a simple problem, but the key is always to ensure that all values

Table 2

Short-Run vs. Long-Run Real Marginal Costs for Energy [43]

(All expressed in 2009 dollars)

	Winter Peak	Winter Off-Peak	Summer Peak	Summer Off-Peak
2010	$0.072	$0.056	$0.075	$0.055
2011	$0.077	$0.060	$0.079	$0.057
2012	$0.084	$0.065	$0.082	$0.061
2013	$0.085	$0.069	$0.085	$0.067
2014	$0.086	$0.071	$0.087	$0.068
2015	$0.086	$0.072	$0.088	$0.068
2016	$0.087	$0.073	$0.092	$0.070
2017	$0.089	$0.076	$0.094	$0.073
2018	$0.092	$0.078	$0.096	$0.076
2019	$0.092	$0.079	$0.098	$0.077
2020	$0.093	$0.080	$0.098	$0.076
2021	$0.091	$0.079	$0.094	$0.077
2022	$0.092	$0.080	$0.097	$0.078
2023	$0.095	$0.080	$0.101	$0.079
2024	$0.099	$0.082	$0.105	$0.084
2025	$0.100	$0.083	$0.107	$0.086
2026	$0.102	$0.084	$0.109	$0.088
2027	$0.104	$0.085	$0.112	$0.090
2028	$0.106	$0.087	$0.114	$0.093
2029	$0.108	$0.088	$0.117	$0.095
2030	$0.109	$0.090	$0.119	$0.097
2031	$0.111	$0.091	$0.122	$0.100
2032	$0.113	$0.093	$0.125	$0.102
2033	$0.115	$0.094	$0.127	$0.105
2034	$0.117	$0.096	$0.130	$0.108
2035	$0.119	$0.097	$0.133	$0.111
2036	$0.122	$0.099	$0.136	$0.113
2037	$0.124	$0.100	$0.139	$0.116
2038	$0.126	$0.102	$0.142	$0.119
2039	$0.128	$0.104	$0.145	$0.122
Levelized Costs				
2010	$0.072	$0.056	$0.075	$0.055
10-year	$0.084	$0.070	$0.087	$0.067
15-year	$0.087	$0.073	$0.091	$0.070
30-year	$0.098	$0.081	$0.105	$0.084

43 Hornby et al, 2009. Appendix B, Table 1.

are accounted for transparently and at least roughly correctly somewhere in the analysis.

4.3. Valuing Power Supply

The electric utility industry has used two very different methodologies to value power supply, and both are in widespread use in the United States today. The first is a "capacity and energy" approach, in which the cost of building and operating power plants is separated into a "capacity" component representing the capital costs of meeting peak demand and an "energy" component representing the remaining costs of power supply. The second approach is a "market pricing" approach, in which the cost of obtaining power supply in a competitive market is measured at different times of the day and year; this latter approach incorporates both capital and operating costs into a single on-peak, off-peak, or even hourly market price.[44]

Both of these methods are relevant and in common use, so below we discuss valuing the displaced power supply benefit of energy efficiency under both approaches.

An important element is identifying the peak savings and energy load shape of savings from energy efficiency measures. Virtually all energy efficiency measures provide meaningful peak load savings, but measuring these savings can be challenging. Many energy efficiency measures, such as air conditioning improvements and thermal improvements to the building envelope, have very high on-peak savings. In one regulatory docket, recognizing the production, transmission, and distribution capacity benefits of residential insulation and window upgrade investments nearly doubled the computed avoided cost by which the programs were measured compared with an energy-only avoided cost calculation, because space conditioning is highly peak-oriented.[45]

4.3.1. Capacity and Energy Approach

The capacity and energy method generally identifies both fixed and variable costs of existing or new generating capacity and associated transmission and measures their expected magnitude over time.

Some analysts attribute all fixed costs as "capacity" related, and only variable costs as "energy" related, whereas others take an economic and analytical approach to attributing costs on a causal basis.

Under a fixed/variable approach, the capital cost of the next power plant (which could be a baseload or peaking unit) would be considered a "capacity" cost, and the variable operating costs would be "energy" costs. In the example below, a baseload plant would have annual capacity costs of $500/kW-year and energy costs of $0.032/kWh, while a peaking unit would have annual capacity costs of $170/kW-year and energy costs of $0.064/kWh.

Table 3

"Equivalent Peaker" Methodology for Classifying Costs Between Baseload, Intermediate, and Peak

Underlying Costs	Baseload	Combustion Turbine	Demand Response
Hourly Application	Baseload	Intermediate	Peaking
Capital Cost/kW	$3,000	$1,000	
Capital Recovery Factor	15%	15%	
Annual Capital Cost $/kW	$450	$150	
Fixed O&M Cost/kWh	$50	$20	$50
Total Annual Fixed Cost	$500	$170	$50
Variable O&M Cost/ kWh	$0.002	$0.004	
Fuel Cost/kWh	$0.03	$0.06	
Average hours run per year	6,000	1,000	50
Hours attributable to column	5,000	950	50
Total Cost:	$692	$234	$50
Attributable to Peak	$50	$50	$50
Attributable to Intermediate Hours	$184	$184	
Attributable to Baseload Energy	$458		
$/kWh by Period	**$0.0916**	**$0.1937**	**$1.0000**

44 Hourly prices do not actually inform regulators or consumers about what the relevant long-run marginal costs are. For example, the nighttime price may be very low when systems include excess baseload capacity, but when a system is in load/resource balance, incremental nighttime load may then require construction of new baseload capacity at a significant multiple to the variable price under temporary conditions of excess capacity.

45 Washington Utilities and Transportation Commission vs. Puget Sound Energy, Docket UE-011570, Exhibit F to Settlement Stipulation, 2002.

Because this approach produces widely varying results, and because it does not consider least-cost critical peak measures like demand-response, analysts have developed more sophisticated approaches to separating "capacity" and "energy" costs, such as the "Equivalent Peaker" (or Peak Credit) approach. This approach looks at the cheapest way to supply peaking services, and counts these as the "capacity" costs for all options, with capital costs in excess of this amount attributed to energy during the hours when more capital-intensive resources will be operated. Table 3 shows how three resources would be separated into capacity and energy costs using this approach.

With this approach, all output of a baseload plant would be valued in the three time periods – $1.00/kWh during the peak hours, $0.1937 during the intermediate hours, and $0.0916 during all other hours. This is only the cost of the plants themselves and does not include transmission, distribution, reserves, risk, or line losses, all of which are discussed separately below. The appropriate capital costs, operating costs, annual operating hours, and capital recovery factors will vary from utility to utility, technology to technology, and plant to plant.

Using this valuation methodology, it becomes clear that if a utility only needs a few hours of peaking power, it should buy a DR measure; if it needs a baseload power plant, the majority of these costs should be recognized as part of providing baseload (i.e., off-peak) service. This allows logical valuation of energy efficiency measures based on their respective load shapes.

With this introduction, we now discuss production capacity and energy costs as components of the value of energy efficiency investments.

4.3.1.1. Production Capacity Costs

The valuation of production capacity will vary depending on how many hours the capacity is required, or more specifically, the manner in which the utility obtains peak production capacity. For sharp, short-term peaking needs,[47] DR – enticing customers to reduce usage through dynamic pricing or contractual load-shedding arrangements – is the lowest cost option. But it is obtainable for only for a limited number of hours per year, 50 hours more or less. Peaking generators like combustion turbines are typically used for loads occurring more often than this. Thus, the value of the highest 50 hours may be valued using the cost of DR, whereas usage in a broader peak period may be valued using the cost of a peak generating resource.

Table 4

ISO-NE Forward Capacity Market Clearing Results for 2016-17 (FCA-7), Connecticut Zone[48]

Need For Resources	Estimated By NEISO	7,603 MW
Qualified Resources	Included in Bids to NEISO	9,082 MW
Starting Bid Price		$15.00/kW-month
Ending Bid Price		$3.15/kW-month (floor)
Bids Received At Floor Price		8,371 MW
Excess of Need		760 MW
Need as % of Bids at Floor		91%
Payment Rate to Winning Bidders for Demand Response	91% of Floor Price	$2.88/kW-month

ISO-NE has allowed DR resources to bid into the local capacity market for several years, and its experience has shown that peaking capacity can be had for approximately $35/kW-year for resources available up to 50 hours per year. This is a fraction of the cost of building peaking power plants, augmenting T&D systems, and providing for the operating costs, fuel, and emissions of such power plants.

Utilities and independent power producers often choose to build baseload power plants to serve more hours of the year, and these power plants can also provide peaking benefits. In valuing the cost of providing year-round energy, only the costs that would be incurred to meet peak needs should be attributed to the peaking capacity function; the balance of costs should be attributed to the year-round energy function.

For example, Pacific Gas and Electric Company (PG&E) recently estimated its production capacity-related costs (attributable only to summer months, on-peak hours) at $109.32/kW-year, or approximately $0.11/kWh based on 1,000 on-peak hours per year.[49] This includes both the peak (DR) and intermediate hours used in the equivalent

47 Often referred to as "needle-peak" loads.

48 Sedlacek, 2013.

49 PG&E. (2013). Cost-Based Rate Drivers, Docket R.12-06-013.

peaker approach described earlier. The California renewable portfolio standard (RPS), requiring utilities to acquire qualifying resources to meet 33 percent of their energy requirements by 2020, affects this calculation.[50] Lowering the total level of consumption, of course, also lowers the amount of high-cost supply required under the RPS.

4.3.1.2. Production Energy Costs

The balance of power supply costs are best viewed as part of the "energy" component of the "capacity and energy" approach to valuation. That is, the excess capital costs of baseload generating units over peaking resources is not associated with meeting peak demand, and is thus not a capacity cost.

PG&E's recent estimate of its production energy marginal costs reflected a range between $0.04/kWh off-peak to $0.06/kWh on-peak.[51] This includes almost exclusively variable natural gas fuel and operating costs, a very narrow measure of "cost." If the capital costs of renewable energy generating facilities being constructed due to the state RPS were included in this measure, these costs would be approximately twice as large. Many utilities fail to recognize these benefits; for example, PG&E excludes these because they are "mandatory" and not "marginal," when in fact, the amount of renewable energy needed is entirely marginal, depending on the underlying load.

Estimating production energy costs can involve a number of issues, including fuel forecasts, energy cost levelization, and consideration of seasonal factors, among others. Because most regulators are already familiar with the process of estimating avoided production costs, however, we have not dwelled on this topic in this paper. Instead we focus on the myriad of other costs that energy efficiency investment can displace.

4.3.1.3. Costs of Compliance with Existing Environmental Regulations

The vast majority of the nation's electricity generators are subject to provisions of state and federal environmental laws regarding releases of pollution into the environment.[52] The set of least-cost solutions to most if not all environmental regulations on the power industry includes energy efficiency. By including energy efficiency, one lowers the cost associated with environmental compliance, while also promoting sound use of energy efficiency as a resource.

Environmental compliance requirements are mandated in such statutes as the Clean Air Act, the Clean Water Act, and the Resource Conservation and Recovery Act. They impose both immediate and future compliance costs on regulated generators in the form of:

- Capital costs and fixed O&M costs for pollution control and monitoring equipment;
- Variable O&M costs associated with pollution control equipment and other compliance activities;
- Allowance costs where a "cap-and-trade" program exists;
- Permit fees;
- Emission fees; and
- Other fees.

These costs are currently included in some utility prices, and more will be included over time. It is important, when forecasting long-run market prices, to recognize that pollution control costs will increasingly be internalized (reflected in energy prices), that new environmental regulations are likely and should be anticipated, and that health and other damage costs of actual emissions (discussed in Section 7) should decline. It is important to count these very real costs once (but not twice), in estimating the value of energy efficiency.

Increased end-use efficiency reduces the need to generate electricity and can thus reduce air emissions, water discharges, and solid waste from regulated generators producing energy on the grid. Avoiding those emissions may reduce environmental compliance costs for generators.

Environmental regulatory requirements and compliance costs can also vary based on a generator's rated capacity, location, fuels, age, and other factors. For example, a generator's costs for allowances under an emissions

50 The requirement for 33 percent renewables has resulted in a significant surplus of supply in California, depressing the market clearing prices. However, because energy efficiency displaces not only the need to dispatch power plants, but also the need to acquire the corresponding share of renewable resources, it may be more appropriate to consider the full value of the avoided new power resources, not just the avoided dispatch of natural gas generation.

51 PG&E. (2013).

52 For more information on this topic see Colburn et al, 2013; Colburn et al, 2012a; Shenot, 2013; Farnsworth, 2011 and Lazar et al, 2011b.

trading program would vary significantly with the amount of electricity it produces, while permit fees or financing costs may not vary at all with output.[53]

A variety of methods and tools for estimating the emissions reductions attributable to energy efficiency efforts have been developed, and they range from very simple to very complex.[54] The process of monetizing avoided compliance costs resulting from reduced emissions can prove challenging, but some details and examples are provided here.

Table 5

Air Pollution Control Retrofit Cost Estimate Ranges[56]

For Coal Generation in the PJM Regional Transmission Organization Interconnection

Control Technology	MW Size Range	Capital Cost ($/kW)	Fixed O&M ($/MW-yr)	Variable O&M ($/MWh)
FGD Range ***(Average)***	28-1,300 MW ***(211 MW)***	$331-$1,149 ***($677)***	$1,580-$44,710 ***($12,100)***	$1.01-$3.81 ***($1.93)***
DSI Range ***(Average)***	43-1,320 MW ***(408 MW)***	$9-$273 ***($89)***	$170-$5,670 ***($1,780)***	$2.00-$15.54 ***($5.71)***
SCR Range ***(Average)***	16-554 MW ***(161 MW)***	$175-$427 ***($263)***	$550-$15,600 ***($4,130)***	$0.20-$1.41 ***($0.47)***
SNCR Range ***(Average)***	45 – 1,300 MW ***(256 MW)***	$11 - $136 ***($48)***	$140-$4,900 ***($1,190)***	$0.34-$2.16 ***($1.12)***
Fabric Filter + ACI Range ***(Average)***	16-1,320 MW ***(299 MW)***	$118-$468 ***($225)***	$520-$9,340 ***($1,190)***	$0.52-$1.59 ***($1.09)***

Capital Costs and Fixed O&M Costs

Generators may need to install expensive pollution control technologies to comply with environmental regulations. Pollution control equipment may be installed at the same time a generating unit is built or be retrofitted to an existing source. Monitoring equipment for some pollutants may also be required. There are both fixed and variable costs of operating and maintaining pollution control and monitoring equipment.[55] In a restructured market like those in New England or Texas, these costs will be reflected in higher nodal energy costs over time. In regions with traditional regulation, they will be reflected in higher utility revenue requirements for production plant – but they are not "capacity" related costs, because they do not really serve primarily in a peaking function.

Existing Generation

Generators usually cannot avoid pollution control retrofits (or their related capital and fixed O&M costs) simply by reducing emissions or discharges. Retrofit costs can be substantial, as shown in Table 5. To the extent that energy efficiency investments can contribute to the early retirement of existing uncontrolled generation, avoiding both the capital and fixed O&M costs associated with environmental retrofits, these savings should be included in avoided costs. In addition, this displaces the damage costs from continued operation, which is addressed below in Section 7.

New Generation

End-use energy efficiency may also defer or eliminate the need for new capacity, but care must be taken to avoid double counting of avoided costs. New capacity cost estimates (addressed in Section 4.3.1.1) normally include the cost of mandatory pollution controls and monitoring equipment.

53 Such fees must still be assigned to the periods when the power plant will be operated, however.

54 Good references on this topic include Keith et al., 2005 and Evaluation, Measurement, and Verification Working Group, 2012.

55 Many state solid waste regulations require the installation of groundwater monitoring well systems and hydrogeologic assessments at facilities storing coal combustion residuals. Air programs around the country rely on continuous emissions monitoring systems (CEMS) to monitor flue gas for various constituents, and are required under the federal Acid Rain and other emission programs. Many pollution control technologies require electricity and/or other variable inputs to operate.

56 PJM Interconnection, 2011.

Variable O&M Costs

As shown in the last column of Table 5, some costs of pollution control vary with the output of the generator. This is because the control equipment itself consumes energy and requires inputs such as catalyst or sorbent that must be periodically recharged, or be maintained on a schedule that varies depending on how often the generation unit operates. Variable O&M costs can be avoided when a generator decreases its output as a result of energy efficiency. Estimates of these costs are generally included in the published O&M data for a particular plant category.

Allowance Costs

Some air pollutants are regulated under federal, regional, or state "cap-and-trade" programs.[57] These programs require generators to acquire emission "allowances" in amounts equal to their actual emissions. Some programs may allocate allowances to generators for free; other programs may require their purchase (e.g., in an auction). In all cases, the total amount of available allowances (and thus emissions) is capped. Generators can buy and sell allowances depending on whether they have more or fewer than they need to match their actual emissions. Thus, allowances monetize the costs of compliance with cap-and-trade regulations.

When energy efficiency investments reduce emissions of a pollutant regulated under a trading program, the affected generators will require fewer allowances for compliance. This will lower those generators' compliance costs. The total amount of allowances available to all regulated sources (i.e., the "cap") does not change, however, and generators whose emissions declined may be able to sell allowances to other parties. Energy efficiency can thus reduce the total demand for allowances across the trading program, putting downward pressure on allowance prices. All regulated sources could thus see a reduction in trading program costs, not just the utility on which energy efficiency is implemented.[58] Alternatively, of course, policymakers could choose to lower the overall cap.[59]

Permit Fees

Environmental regulators typically charge fees for processing and administering required permits.[60] Generally, permit fees cannot be avoided by reducing emissions or discharges. But if energy efficiency investments facilitate the early retirement of an existing generator, or defer or eliminate the need for new capacity, then avoided permit fees should be recognized as a component of avoided costs. Where permit fees do vary with emissions levels and can be reduced through energy efficiency investments, direct cost savings should be recognized as a benefit.[61]

Emission Fees

Federal National Pollutant Discharge Elimination System (NPDES) (water) permits contain fee schedules that vary based on the amount of permitted discharge. Under the Clean Air Act, state and local air pollution control agencies collect annual emission-based fees from regulated sources. A 2011 National Association of Clean Air Agencies (NACAA) survey provides an informative snapshot of the levels of some of these fees.[62]

57 Examples of trading programs include the federal Acid Rain Program for sulfur dioxide emissions, the nine-state Regional Greenhouse Gas Initiative in the northeast United States, Illinois' Emission Reduction Market System for volatile organic compounds, and California's Greenhouse Gas Cap-and-Trade Program.

58 Effectively, energy efficiency can create "DRIPE for allowances." Energy efficiency and unanticipated emissions control developments (e.g., control technologies, fuel switching) can and have had a huge impact on market clearing prices for allowances. If the effect is local or regional, it will be reflected in regional market clearing prices for electricity. Conversely, the market for SO_2 allowances under the federal Acid Rain program (and potentially for CO_2 in the future) is traded in a national market. As a result of such developments, SO_2 allowance traded at prices an order of magnitude below original estimates within a few years after the program commenced, but will be reflected in national prices for SO_2 (or CO_2), not in regional power prices, and so will be undercounted as a benefit of local action.

59 This occurred, for example, in the case of the Regional Greenhouse Gas Initiative in 2013.

60 Under the federal Clean Air Act, most generators are required to obtain a construction permit from their state or local air pollution control agency before initial operation, as well as an operating permit requiring periodic renewal. Likewise, under the National Pollutant Discharge Elimination System (NPDES) program, all facilities that discharge pollutants from any point source into U.S. waters are required to obtain a permit.

61 For a description of fees charged by state air agencies, National Association of Clean Air Agencies, 2011.

62 Ibid

Table 6

A Sampling of State Fees for Air Pollutant Emissions		
State	**Source or Pollutant**	**Fee per Ton Emitted**
Arkansas	All air pollutants	$22.07
Colorado	Criteria pollutants	$22.90
	Other pollutants	$152.90
Georgia	Coal-fired electric generators	$35.84
	All other facilities	$34.00
New Hampshire	All air pollutants	$205.27

Some jurisdictions limit the maximum number of tons for which emissions fees are charged for any one pollutant emitted by any one permitted entity in a year. To the degree that a jurisdiction has such a limit and generation sources exceed it, reducing emissions through energy efficiency may not translate into reduced emission fees, but may reduce the risk for much higher non-compliance penalties.

Other Fees

Some states assess fees for the cost of regulatory inspections and other activities that do not fit within the categories of permit fees or emission fees. Such other fees may or may not be avoidable through reduced output resulting from energy efficiency investment, but are always avoided if energy efficiency enables complete retirement of a power plant or avoidance of a new or upgraded one.

4.3.1.4. Costs of Compliance with Expected Future Environmental Regulations

The prior section explained how compliance with *current* environmental regulations can create immediate and future utility system costs, and how energy efficiency investment can help avoid several of those costs. This section considers costs stemming from expected *future* environmental regulations, and how energy efficiency can help avoid these costs as well.[64]

If environmental harms are not controlled, then their associated environmental damage remains an externality, discussed in Section 7. In almost all cases, future environmental control costs (discussed here) are smaller than damage costs. The crucial issue is that analysts should consider either control costs (future regulations) or damage costs (no future regulations) in examining the cost of power production. Zero is never the "right number" for matters such as criteria air pollutant emissions and water discharges, CO_2 emissions, once-through cooling, or coal ash management. A probability-weighting between the two, as illustrated in Table 7, may be reasonable where future regulation is uncertain.

The Clean Air Act requires regular scientific reviews and, if warranted, updates of air quality standards, as this paper discusses below. New regulations are also expected, for example, under the Clean Water Act and the Resource Conservation and Recovery Act (RCRA). Electric generators can expect to face additional compliance costs from these new regulations.[65]

In general, the categories of costs associated with future regulations echo those for current regulations: capital costs and fixed O&M costs, variable O&M costs, allowance costs, permit fees, emission-based fees, and other fees. Generators can expect significant capital costs and fixed O&M costs for pollution control and monitoring equipment. They should not anticipate avoiding the need for pollution control retrofits or their related costs simply by reducing emissions or discharges. However, utilities can expect to avoid these costs to the extent that

63 For calendar year 2012 emissions. See: http://des.nh.gov/organization/divisions/air/pehb/apps/crss/emissions-fees-notice.htm

64 An argument can be made for treating compliance with future regulations as either a utility system cost or as a societal cost. Pragmatically, the probability of regulation increases over time, and the expected cost of future regulations is never zero. Many utility IRPs do multiple scenarios, with carbon costs (as an example) phasing in at different times and at different levels, in order to consider the potential impacts. However, whenever a potential future regulation is not included in utility costs, then the resultant damage costs – for whatever period is assumed prior to promulgation of regulations – should be included in the SCT. For particularly dangerous pollutants such as PM2.5, the damage costs are an order of magnitude greater than the compliance costs, and it probably makes sense to simply assume compliance sooner rather than later.

65 For example, the Mercury Air Toxics Rule that was finalized in April 2013; see: http://www.gpo.gov/fdsys/pkg/FR-2013-04-24/pdf/2013-07859.pdf; requirements to reduce pollution transported across state lines; and even requirements to reduce GHG emissions.

Table 7

Probability-Weighting of Prospective Emission Regulations

(Note: All values are strictly illustrative.)

Emission Type	Probability of Regulation	Mitigation Cost	Damage Cost	Probability Weighted PAC/TRC Cost	Probability Weighted Societal Cost
Mercury-Lb	75%	$33,000	$181,500	$24,750	$70,125
$PM_{2.5}$-Ton	50%	$13,000	$60,000	$6,500	$36,500
CO_2-Ton	25%	$8	$80	$2	$62

energy efficiency investment contributes to the retirement of existing uncontrolled generation or the deferral or avoidance of new generation.[66] As noted earlier, care must be taken to avoid double counting of avoided costs.

Some of the costs associated with new pollution control equipment requirements will vary with the output of the generator. This is because the equipment itself consumes energy, and additional inputs such as sorbent also vary depending on how often it operates. These variable O&M costs can be avoided when a generator decreases its output as a result of energy efficiency.

If new regulations employ allowance trading as a compliance option, greater energy efficiency investment can be expected to lower electricity demand and thereby lower demand and prices for allowances in cap-and-trade jurisdictions. As noted previously, however, policymakers could revisit and adjust the level of the cap. Generators can also expect permit fees, emissions fees, and other related fees. To the degree that the fees vary with emissions, the fee payments can be reduced by energy efficiency investments.

The expectation of future regulation is not mere speculation.

The examples below illustrate a key point: firms subject to environmental regulations can anticipate additional, more stringent regulations in the future and would benefit from planning even *before* they know the precise details of what will be required. The expectation of future regulation is not mere speculation. Firms can address the uncertainty of future regulatory costs in various ways (e.g., assigning a probability-weighted cost for each risk, assessing a range of possible compliance costs).

Clean Water Act — Cooling Water Regulations

Section 316(b) of the Clean Water Act requires protection for fish and other biota from cooling water intake structures, and addresses harms associated with once-through cooling systems.[67] Approximately 36 percent of U.S. generating capacity uses once-through cooling.[68] The EPA's proposed rule considers various technology options, two of which incorporate expensive closed-cycle cooling designs. The Electric Power Research Institute estimates that potential costs of closed-cycle cooling retrofits, including capital costs, and costs resulting from lost revenue owing to outage time from retrofit installations and resulting inefficiencies in plant operation exceeds a net present value of $95 billion.[69] Although the majority of the units to which this applies are small fossil units also facing cost increases for other environmental retrofits, the magnitude of these costs for large nuclear units is potentially quite large. Enercon estimates that installing closed-cycle cooling on U.S. nuclear plants would cost $83 billion.[70] Parasitic load (i.e., the electric power required to run the cooling towers) reduces the power delivered to the grid when the plant is operating, and thus increases the cost per kWh of power actually received.

The San Onofre nuclear generation station was closed in 2013, in part because the cost of capital upgrades (including potential costs for cooling towers) exceeded the expected value of energy from its two units. These are the

66 To the extent environmental impact is avoided, it is a utility system cost; otherwise it is a damage cost to society and should be considered in the SCT.

67 The EPA is expected to finalize its 316(b) rule in the summer of 2013. The EPA has also issued a proposed wastewater rule that will affect electricity generators. 75 Fed. Reg. 35127–35264. Final action on this rule is expected by May 22, 2014.

68 Enercon, 2010.

69 Electric Power Research Institute, 2011. EPRI assumes facilities would retrofit with wet mechanical draft cooling towers, a commonly used closed-cycle cooling technology.

70 Enercon, 2010b.

Table 8

Illustrative Nuclear Plant Cooling Cost Estimates, $ in Billions [71]							
Plant Name	**Capital Cost for Cooling Towers**	**Replacement Power Costs Due to Down Time**	**Total Initial Capital Cost: Capital and Lost Generation**	**Outage Duration (Months)**	**Number of Units**	**Total Plant Output (MW)**	**MW to Operate Cooling Towers**
Diablo Canyon[72]	2.7	1.8	4.5	17	2	2,310	55
Indian Point[73]	1.2	1.0[74]	2.2	10	2	2,158	88
San Onofre[75]	0.6	2.4	3.0	21	2	2,150	143

third and fourth nuclear units retired in 2013, all owing to high costs of capital improvements needed for these aging units to remain viable.[75]

RCRA — Coal Ash Regulations

In June 2010 the EPA proposed a rule to regulate the disposal of coal combustion residuals (CCR) produced by electric utilities and currently stored in open surface impoundments.[77] The EPA put forth three alternative regulatory approaches. The first would list CCR as a "special waste" subject to stringent hazardous waste management standards under Subtitle C of RCRA. A second, less expensive approach would treat CCR under the less stringent Subtitle D of RCRA, classifying them as solid waste and issuing national criteria for their disposal. The EPA's third approach (known as "D Prime") would allow the continued use of surface impoundments until the end of their useful life.

EPRI analyzed total incremental costs to the industry of the EPA's Subtitle C approach, the most stringent of the three options. Over a 20-year period, it would cost the industry $54.66 to $76.84 billion present value (at a discount rate of 7%).[78] According to the EPA, Subtitle C costs would be $1.4 billion annually and $20.3 billion in total. The EPA estimates that Subtitle D costs would be $587 million annually and $8 billion in total.[79]

National Ambient Air Quality Standards and State Implementation Plans

The Clean Air Act currently requires the EPA to establish National Ambient Air Quality Standards (NAAQS) for certain pollutants. The law also requires the EPA to re-examine public health data every five years and determine whether changes to NAAQS are warranted.[80]

In areas where ambient air quality does not meet NAAQS, state or local regulators must develop a state implementation plan (SIP) to meet them by a specified deadline, and the EPA must approve the plan.[81] In many cases, SIPs will include new regulatory requirements on electric generators. It is thus reasonable to anticipate future regulatory compliance costs stemming from SIPs in at least three circumstances:

71 Based on Enercon, 2010. Figure "Sample Nuclear Cost Estimates."

72 Enercon, 2009a.

73 Enercon, 2010a.

74 Calculated based on average $70/MWh spot price for New York.

75 Enercon, 2009b. On June 7, 2013, Southern California Edison announced plans to retire San Onofre Station.

76 Sewell, 2013.

77 The EPA proposed the rule on June 21, 2010. It has not set a publication date for the final rule. Ash pond closures can be expected from 5 to 7 years after final rule is issued. See http://www.epa.gov/wastes/nonhaz/industrial/special/fossil/ccr-rule/index.htm

78 For other assumptions, see: Electric Power Research Institute, 2010. Pages 18-21. The analysis does not include disposal site construction and operation costs.

79 Frequent Questions: Coal Combustion Residues (CCR) – Proposed Rule. See: http://www.epa.gov/osw/nonhaz/industrial/special/fossil/ccr-rule/ccrfaq.htm#20. Uses a 50-year present value basis at a 7-percent discount rate.

80 Specifically, this requirement lies with the EPA's Clean Air Science Advisory Committee.

81 Refer to Colburn et al, 2012a.

- Part of a state has already been designated as nonattainment because it does not meet a NAAQS, and the state is developing its SIP;
- Ambient air monitoring data suggests that part of a state is not meeting a NAAQS, even though it has not yet been designated as nonattainment; or
- The EPA's Clean Air Science Advisory Committee has recommended that the agency tighten a NAAQS (as it has recently for ground level ozone), and ambient air monitoring data suggests that part of a state would not attain the more stringent standard.

In these cases, "on the books" regulations are likely to be insufficient, and it would be reasonable and prudent for generators to plan for more stringent requirements. To what degree future requirements are apt to impose costs on electric generators is a question that must be assessed on a case-by-case basis, but least-cost compliance solutions will include energy efficiency.

As a rule of thumb, generators in nonattainment areas have historically faced regulatory requirements that are more stringent and costly than those in areas that meet the NAAQS. In fact, a nonattainment designation under the Clean Air Act can result in significant financial repercussions for states and emitters, including loss of federal highway funding, increased motor fuel costs owing to fuel reformulation requirements, enhanced regulatory oversight (e.g., permitting requirements), and economic development sanctions (e.g., mandatory emissions offsets).

Interstate Air Pollution Transport

Air pollution can be transported across state lines by prevailing winds, of course, and the Clean Air Act includes "good neighbor" provisions that impose responsibilities on states whose emissions are found to contribute substantially to nonattainment in a downwind state.[82] The EPA has determined that 28 states are doing so, and has focused much of its regulatory attention on electric generators.

However, the EPA's attempts to address this issue through specific regulations have thus far been rejected by the courts.[83] Most recently, the Cross State Air Pollution Rule was struck down. Nevertheless, the Clean Air Act's good neighbor provisions still apply: states may not contribute significantly to nonattainment, or interfere with maintenance of attainment, in any other state. This again suggests a reasonable likelihood of future regulations that could impose substantial costs on generators.

The costs of compliance with the EPA's ultimate interstate transport rules cannot be known until their adoption, but they almost certainly will not be zero. Each of the prior rules adopted by the EPA (but rejected by the courts) has been accompanied by assessments by the EPA and others of likely compliance costs. These documents could inform an assessment of future regulatory costs that could be avoided via emissions reductions resulting (at least in part) from energy efficiency. In short, energy efficiency at scale may be a cost-effective "compliance strategy" (or a strategy to avoid compliance requirements and costs) by reducing emissions in order to attain and maintain adherence with NAAQS.

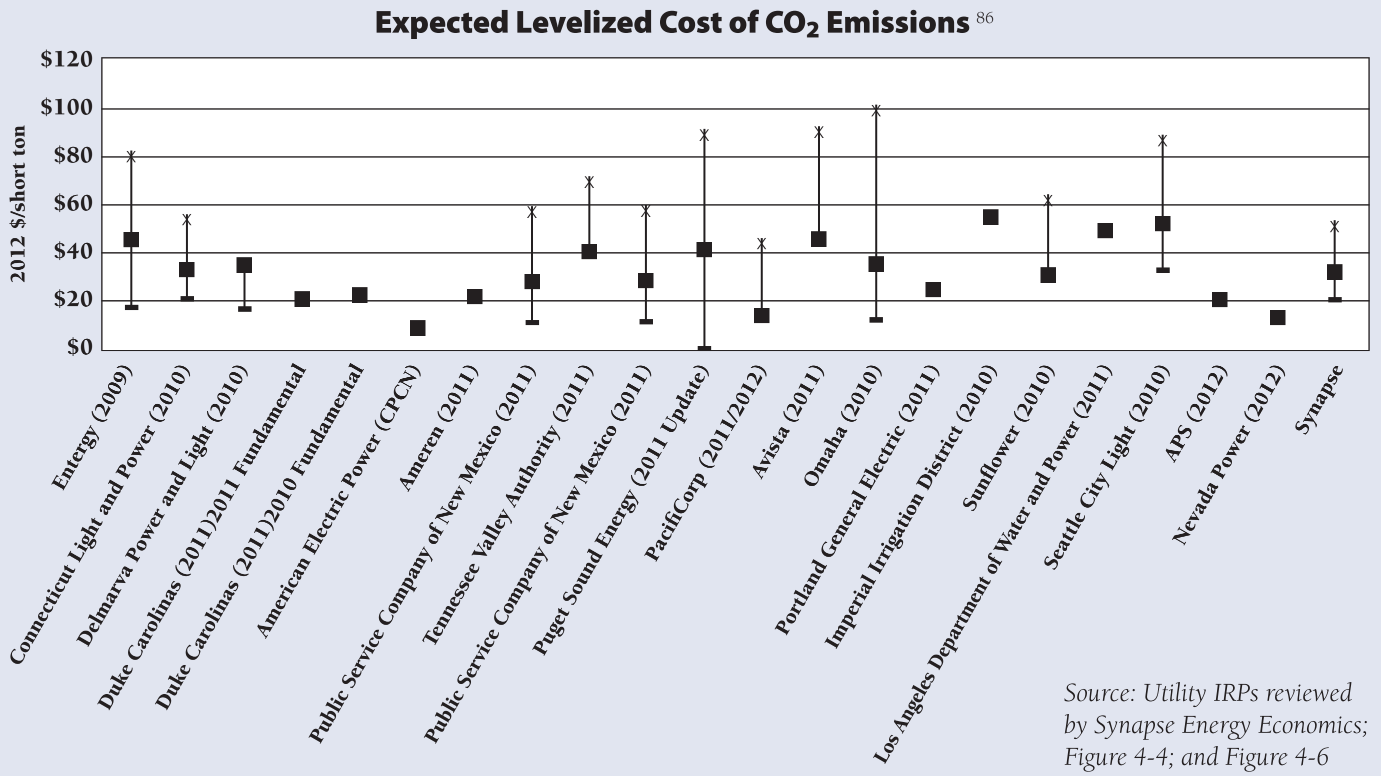
Federal Greenhouse Gas Regulations

The U.S. Supreme Court ruled in 2007 that CO_2 falls within the Clean Air Act definition of air pollutant and further ruled that the EPA must regulate CO_2 emissions if the EPA determines that emissions may reasonably be anticipated to endanger public health or welfare. The EPA made such a determination in 2009. With it, federal regulation of CO_2 and other greenhouse gas (GHG) emissions from electric generators became inevitable. Although the timing and stringency of such regulations remain far from certain, only a revision to the Clean Air Act

82 On July 12, 2013, the U.S. Court of Appeals for the Third Circuit ruled that the Clean Air Act does not foreclose the EPA from forcing upwind states to address air pollution that significantly contributes to a downwind state's nonattainment of an NAAQS. See GenOn REMA LLC v. EPA, No. 12-1022. The court in this decision distinguished the process set out in Section 126 of the Clean Air Act process from the "SIP call" process set out in Section 110 that was under consideration in a recent D.C. Circuit decision: EME Homer City v. EPA, No. 11-1302 (D.C. Circuit). The Homer City decision vacated the EPA's Cross-State Air Pollution Rule. For a discussion of the implications of the Homer City decision, see Colburn et al., 2012b.

83 On January 24, 2013, the U.S. Court of Appeals for the D.C. Circuit denied the EPA's petition for rehearing en banc of the Court's August 2012 decision to vacate the Cross-State Air Pollution Rule. http://www.cadc.uscourts.gov/internet/opinions.nsf/19346B280C78405C85257A61004DC0E5/$file/11-1302-1390314.pdf; On March 29, 2013, the U.S. Solicitor General petitioned the Supreme Court to review the D.C. Circuit Court's decision on the Cross-State Air Pollution Rule. See: http://www.epa.gov/airmarkets/airtransport/CSAPR/pdfs/EME_Homer_City_Pet.pdf

Figure 4



Source: Utility IRPs reviewed by Synapse Energy Economics; Figure 4-4; and Figure 4-6

by Congress or a reversal by the Supreme Court of its prior decisions could forestall some form of regulation of CO_2 emissions.

With this handwriting on the wall, more and more energy efficiency program evaluators have begun to factor costs of compliance with federal GHG regulations into their cost-effectiveness calculations. This is typically done by assuming a fixed regulatory compliance cost for each ton of emissions.[84, 85] Utilities and energy efficiency program evaluators have used a variety of methods to develop assumed per-ton compliance costs for GHG regulations. Figure 4 shows considerable variation in the costs U.S. utilities have assumed for CO_2 emissions in recent planning documents; their assumptions range from nearly zero to almost $100 per ton.

Of note, most assessments of future GHG compliance costs are not based on an assessment of the regulations that are likely to be developed under the federal Clean Air Act. Instead, most are based on assessments of the costs of complying with proposed federal legislation, the costs of meeting assumed national emission caps, or a calculated social cost of carbon (considering the societal impacts of climate change).

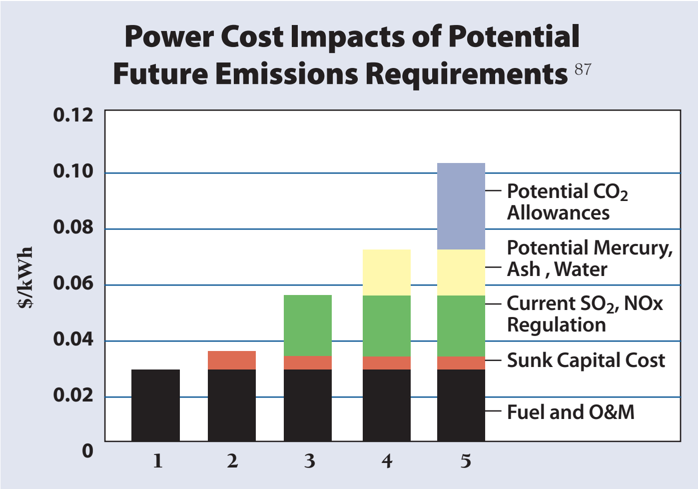
Figure 5 shows how adding future regulations incrementally to the current cost of operating a power plant can change the expected cost of power. In many cases, the cost of upgrading an older power plant may exceed the cost of building a newer, cleaner unit, in which case the cost of a new unit may be more relevant to the valuation of energy efficiency benefits for use in cost-effectiveness tests.

84 In jurisdictions that already have regional or state GHG regulations on the books, care must be taken not to double count local and federal compliance costs.

85 The regulatory mechanism for a fixed cost per ton could be either a trading program, which would lead to a per-ton cost for obtaining allowances, or an emissions tax, which would be functionally equivalent to an emissions fee. However, neither a trading program nor an emissions tax is inevitable. These are just simple, shorthand mechanisms for assessing future regulatory compliance costs, which could come in other forms as well. Compliance requirements could ultimately take the form of an emissions limit (e.g., lbs of GHG emitted per MWh of generation) or a control technology requirement (e.g., 90-percent carbon capture and sequestration) as well.

86 Wilson et al, 2012.

Figure 5



In recognition of the likelihood of these future regulations, prudent regulators and utilities should include an assessment of retrofit-versus-retirement costs for all thermal resources in each utility's IRP. The assessment should include a risk assessment of the costs that will be incurred in the event of sudden failure or mandated retirement, in addition to the expected costs of all future regulations under consideration at the time of the assessment. This creates the basis for comparison with energy efficiency opportunities – the higher the expected cost of continuing to operate a thermal power plant, the higher the cost-effectiveness threshold for energy efficiency.

4.3.1.5. Transmission Capacity Costs

This section and Section 4.4, which addresses distribution capacity benefits, are a brief overview of an important topic in energy efficiency: targeting locations on the grid where significant upgrade costs can be avoided. A separate RAP paper addresses this topic in greater detail.[88]

Energy efficiency investments can reduce loads during peak periods. When this is achieved, the utility system need for transmission capacity is reduced. Savings on transmission capacity can be significant.

Typical transmission costs range from $30/kW-year to $100/kW-year, but these costs are extremely location-specific.[89, 90] The process for estimating the effect on transmission requirements requires knowing the resource shape of the energy efficiency measure – how much of the energy is saved at different times. DR measures also reduce peak loads, and thus may also reduce transmission needs. When quantifying the transmission savings from energy efficiency, location is critical because transmission limitations are location-specific. The targeting of energy efficiency programs to avoid new transmission facilities (in addition to providing valuable energy savings) is increasingly common.[91]

Knowing the coincidence of the energy savings from energy efficiency measures with the transmission peak demand period may require location-specific analysis, but one should not assume that transmission costs are purely associated with providing peaking capacity.[92] Many peaking generating facilities are located near load centers specifically in order to avoid additional transmission costs.

There are several ways to value transmission capacity costs. Major utilities prepare periodic cost of service studies to support state and federal rate filings. These studies normally isolate transmission costs as a separate category. Both "embedded" and "marginal" cost studies are often prepared. Embedded cost studies show the average cost of existing transmission resources; this is useful for estimating the cost of avoided transmission, but because it looks back at past investments, may not fully reflect today's costs for new facilities. Marginal cost studies look at the estimated

87 Lazar & Farnsworth, 2011. Figure 12.

88 Neme et al, 2012.

89 Ibid, P. 3

90 Long transmission distances in the western United States typically involve much higher total transmission costs, but often a significant portion of these costs are classified as energy-related, not capacity-related, because they are incurred to move power from remote baseload or wind generating plants to a service territory. The costs of these "generation-specific" transmission facilities are not good proxies for the transmission capacity costs avoided.

91 For example, Efficiency Vermont's 2012 Savings Claim Summary separately identifies energy efficiency implemented in two small geographic areas where the goal is to avoid transmission upgrade expenditures. The Bonneville Power Administration has applied non-transmission alternatives in the form of targeted energy efficiency programs in several locations. PG&E has used both energy efficiency and local solar resources to displace transmission upgrades. These are all discussed in greater detail in Neme et al, 2012.

92 Transmission facilities are often built, at least in part, to facilitate economic energy sales and exchanges between regions during non-peak periods.

costs for new transmission facilities, and therefore provide a better estimate of the transmission value of energy efficiency investments.

It is important to recognize that DR measures in proper locations avoid the need not only for generation, but also for transmission to serve needle-peak loads. Similarly, combustion turbine and other power plants used for peaking purposes are often built close to loads to avoid transmission costs. Therefore transmission costs generally will be most attributable to other hours, when remote generation from coal, nuclear, hydro, or other baseload and renewable resources is the typical source of supply.

Returning again to the example of PG&E, it recently estimated marginal transmission-related capacity costs to be $71.13/kW-year, or approximately $0.02/kWh at an annual load factor of 50 percent.[93] By contrast, Niagara-Mohawk (New York) estimated its marginal transmission costs at only $8.21/kW-year; the dramatic difference is because Niagara-Mohawk is in the New York Independent System Operator, where most transmission costs are reflected in the market-determined locational marginal price (LMP) process, not in the retail rate setting process (which includes only utility-owned facilities, mostly the lines that connect substations to the transmission hubs). It is important to ensure that all relevant marginal costs are accounted for in valuing energy efficiency benefits. As this example shows, not all regions, countries, or utilities measure these benefits in the same way. The essential element for cost-effectiveness is to ensure that all transmission benefits are reflected somewhere in the calculation, and not inadvertently ignored.

4.3.2. The Market Pricing Approach

The alternative to the "capacity and energy" approach to valuing power supply is to use a more market-driven approach. This is commonly done in regions where the electric utility industry has been restructured into organized markets, and power supply has been separated from the electricity distribution function. In these regions, consumers pay the regulated utility (directly or indirectly) for the cost of providing distribution service, and a market-determined price for bulk power supply (i.e., production and transmission).

In regions where restructuring has occurred, markets determine LMP at numerous specific points (nodes) on the grid, reflecting prices as bid by generators. These prices are generally determined at least hourly, and in some places as frequently as every five minutes. The LMP is an integral figure, normally expressed in dollars per MWh, reflecting the combination of production capacity costs, production energy costs, and identified "congestion" costs to provide power at each node for each time period. It also includes internalized environmental compliance costs, because it can be assumed that bids from electric generators in restructured regions reflect those environmental regulatory requirements, costs, and risks to which they are subject.

In some regions, the LMP also includes transmission costs to the node being priced; in others, transmission is assigned a price separately. In the ISO-NE, for example, the LMP is for energy only; transmission costs are allocated on a system-wide coincident peak basis. Where the LMP does not include transmission costs, they should be separately included in the costs avoided by energy efficiency measures.

The availability of LMP makes possible greater precision – temporally and geographically – in calculating the value of energy savings provided by energy efficiency measures. Calculating this value, however, requires evaluators to possess an equally precise understanding of the temporal and geographic distribution of the energy savings that the measures provide. Evaluators rarely have this information, in which case system-wide avoided costs should be used.

This general approach is very useful for valuing energy efficiency savings, but care should also be taken to ensure that the long-run savings – not just short-run savings – are considered. In a year of extreme weather, or when multiple generating resources are out of service simultaneously, LMPs may spike, and conversely, in mild weather they may slump well below replacement cost.

A region in temporary surplus is likely to have artificially low LMPs, and one in shortage is apt to have inflated LMPs. Because energy efficiency is typically a long-lived resource, it is important to measure long-run costs that will be incurred at the nodes, not just short-term prices. For example, the spot-market values for off-peak and intermediate hours in Table 9 are significantly lower than the long-term values for the same region shown in Table 2 in Section 4.2.

Restructured regions like New England and Texas are discovering that market pricing alone does not entice

93 PG&E Op. Cit.

Table 9

Example of Locational Marginal Prices in ISO-NE, 2010 [94]

	Off-Peak	Intermediate	On-Peak
Boston	$0.0305	$0.0547	$0.1725
Connecticut	$0.0314	$0.0581	$0.1790
Date/Time	Mar 15 4AM	June 24 9AM	July 6 5PM

independent investors to build power plants in advance to assure reliable system service, and therefore spot market prices are not good indicators of long-term values. ISO-NE has instituted a framework of paying capacity reservation payments in addition to the market clearing prices for power. Where market clearing prices are used to value energy efficiency benefits, it is thus essential to ensure that the marginal cost of reliability services – including generation capacity costs, ancillary services, and system administration – are also included in the calculation. It is also essential that forecast market prices for the lifetime of the efficiency measure be considered, not just current market prices. Therefore, the long-run avoided costs shown in Table 2 in Section 4.2 are more appropriate than the short-run costs shown in Table 9.

Regulated utilities often rely on market purchases for a portion of their power supply, and acquire the balance as owners or under long-term contracts. For these utilities, published "avoided costs" may look at market price forecasts as well.

The bottom line is that short-term market prices are not representative of long-term values. In competitive supply regions like Texas and New England, regulators select measures of long-run marginal cost that are developed with some independence from the short-term market clearing prices. Options include a traditional cost-based approach, a forward capacity market, or a periodic all-source auction where bidders are committing to a long-term supply arrangement.

4.4. Distribution Capacity Costs

Energy efficiency measures reduce peak loads at the customer premises. This reduces the need for augmentation of the distribution system capacity. To an even greater degree than production or transmission, location is crucial in determining the distribution capacity benefits of energy efficiency. Some distribution circuits may have no expected need for capacity upgrades, whereas others could have imminent and significant costs pending if local peak demand reductions cannot be achieved. Most are in between, requiring periodic rebuilds that provide opportunities for optimization of capacity.

In a 2002 Puget Sound Energy rate proceeding, residential energy efficiency measures were assigned specific production, transmission, and distribution capacity values for the first time. The result was a near doubling of the allowed utility financial support for low-income weatherization measures, because the winter peak demand savings were very valuable on this winter-peaking utility system.

Utility marginal cost studies typically value distribution system capacity costs at $50/kW-year to $100/kW-year, based on the utility forecasted distribution system upgrades planned in the 5- to 10-year time horizon.[95] However, whereas electricity rates are based on *average* distribution costs including operating expenses, energy efficiency avoids *marginal* distribution costs. The marginal costs typically involve much higher capital costs than historical costs on which rates are computed, but little in the way of operating costs (based on assuming these are likely to be staffing costs that do not vary with demand). There are many ways of measuring marginal distribution costs, but not a lot of consistency. Some utilities assert that efficiency avoids no distribution costs whatsoever, whereas others look methodically at their distribution system maintenance and upgrade plans in estimating marginal distribution capacity costs. Reducing system demand will almost always reduce distribution capacity costs, however, so the correct value will rarely be zero.

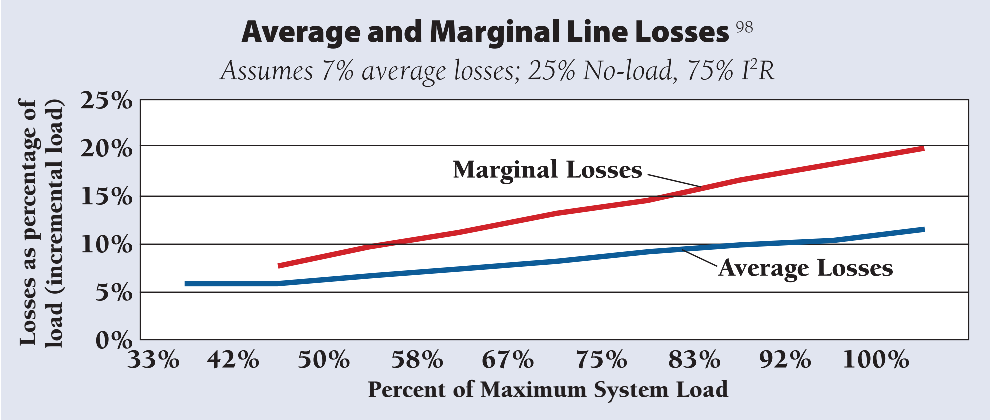
PG&E has estimated its primary voltage distribution capacity costs to be $96.43/kW-year, and secondary voltage

94 ISO New England. Locational Marginal Prices for CY 2010. Available at: http://www.iso-ne.com/markets/hst_rpts/hstRpts.do?category=Hourly

95 Neme et al, 2012. p. 4.

costs to be $1.37/kW-year.[96] Niagara-Mohawk has estimated its distribution capacity marginal costs to be $96/kW-year for primary and secondary combined, quite similar to that of PG&E.[97]

Figure 6



4.5. Line Losses

Owing to line losses associated with moving power from generating stations to customers, energy efficiency savings at the customer premises displaces the need for a much larger amount of energy supply at the bulk power level.

While average line losses are in the range of six to ten percent on most U.S. utility grids, they increase exponentially as power lines become heavily loaded. Avoiding a small amount of load at the highest peak hour can reduce line losses by a much larger than average amount. Marginal line losses at peak periods – those avoided by energy efficiency – can be as much as 20 percent, as illustrated in Figure 6. Attention to line losses reinforces the value of examining locationally specific avoided costs when evaluating energy efficiency programs.

4.6. Reserves

Utility systems carry "reserves" in the form of generating capacity or DR resources that can provide immediate backup service if a power plant suddenly goes off line. In some cases, these resources are maintained or acquired by individual utilities, whereas in others, the balancing authority or regional transmission operator acquires them centrally and charges each user as a function of local peak demand. Typically, reserve requirements reflect a percentage of the demand at any point in time; for thermal systems, reserves are typically 13 to 15 percent of demand. Capacity savings calculated for energy efficiency measures at the meter thus need to be "grossed up" to account for avoided reserve requirements resulting from the lower load.

As noted previously, a reduction in peak demand at the customer premises from energy efficiency investments translates into much larger savings at the generation level owing to avoided marginal peak line losses. The same is true with respect to reserves; a one-kW reduction in usage at the customer meter is worth far more than one kW at the generation level.

Putting both line losses and reserves together, an energy efficiency measure with high on-peak savings can provide approximately 1.4 times the generation capacity benefits of the energy savings measured at the customer premises. Table 10 compares a lighting efficiency project with a low peak coincidence factor to an air conditioning measure with a much higher coincidence factor. The air conditioning measure provides much more in expected capacity savings at the generation level at the time of the system peak than the energy savings expected at the customer meter at that time. This includes avoided marginal on-peak line losses, and a compounded benefit in the form of avoided reserves. These additional system savings reflect a very valuable attribute in the valuation of energy efficiency benefits.

Table 10 shows how the savings measured at the

96 Distribution lines on the high-voltage side of the distribution transformer are called primary distribution lines or primaries. Those on the low-voltage side of the distribution transformer are called secondary distribution lines or secondaries. Primary lines have voltages ranging from 2,300 to 39,000 volts. Common primary line voltages are 2,300, 4,160, 12,470, 13,800, 25,000, and 34,500 volts, depending on which distribution voltages a utility uses. Common secondary line voltages are 120, 208, 240, 277, and 480 volts. (Source: http://epb.apogee.net/foe/ftdsd.asp)

97 New York State Public Service Commission, 2012. Exhibit (E-RDP-9)

98 Lazar et al, 2011a.

99 Ibid.

Table 10

Line	Peak Capacity Savings from Energy Efficiency Investments [100]	Lighting	Air Conditioning
1	kW Savings at Customer Meter	10	10
2	Coincidence Factor	0.25	0.75
3	kW Savings at Customer Meter at Peak (1 X 2)	2.5	7.5
4	Marginal Line Losses At Peak @ 20% (3 / (1 - 20%) -3)	0.625	1.875
5	kW Savings at Busbar (3 + 4)	3.125	9.375
6	Reserve Margin Requirement	15%	15%
7	Avoided Reserve Capacity (@ 15%)	0.47	1.41
8	kW Savings At Generation Level (5 + 7)	3.59	10.78

customer meter translate into savings at the transmission level. First, the peak demand at the customer meter is unlikely to be perfectly synchronized with the system peak demand, so a "diversity" adjustment occurs, which is large for end-uses that are not well correlated with peak demand, and small for those that are. Then the marginal line losses are added, to determine the peak capacity that needs to be available from the bulk power supply system. Finally, the reserves needed are added. If peaking resources are not located near load centers, an additional factor for avoided transmission capacity would be needed. The result is that the capacity needed from the bulk power system (shown on Line 8) is much larger than the capacity required at the customer's meter (shown on Line 3).

4.7. Risk

Utility resource planning – particularly involving the construction and operation of supply resources – is an uncertain science that involves many risks. Such risks include:

- Long lead times for generation and transmission;
- Risk of capital investment project cost overruns;
- Risk of new environmental or other regulations that may add cost, introduce delay, or lead to early retirement;
- Risk that the load forecast is significantly wrong;
- Risk of fuel price volatility; and
- Risk that completed projects will fail after construction, like the Three Mile Island Unit #2 and San Onofre nuclear plants, or the Kleen Energy gas-fired plant in Middletown, CT.[101]

Energy efficiency measures decrease risk in many ways. Energy efficiency programs are unique in that they consist of thousands of small discrete resources that cannot fail all at once, and are therefore inherently less risky in terms of failure than a power plant. Extensive analysis has shown that acquisition of a portfolio of resources consisting of a large number of discrete small units is inherently more reliable and predictable than a portfolio of a smaller number of larger units. In addition, resources with only a short lead-time are preferred over resources that take years to build.[102] Energy efficiency is a highly predictable and reliable resource that enables the utility system and society as a whole to avoid the risk of surpluses, shortages, and periodic outages. Some of this risk avoidance accrues to society and will be addressed in Section 7.3.

Efficiency programs are also readily scalable; they can be ramped up (or down) much faster than new supply resources can be built if load rises more rapidly (or slowly) than expected. Additionally, because it can be added in increments, energy efficiency may buy time to examine the need for large projects; ConEd found that approximately one-third of the time, the transmission and distribution capacity projects "deferred" by energy efficiency upgrades were ultimately never needed at all.[103]

Finally, energy efficiency in new building construction, whether in the form of codes and standards or incentive programs, offers a unique benefit. If each new, efficient home uses half as much energy as a conventional home, and the number of new homes to be built is uncertain, choosing the more efficient route means that the "jaws" of uncertainty in future electricity demand are reduced by half.

For this reason, utility resource planning that recognizes

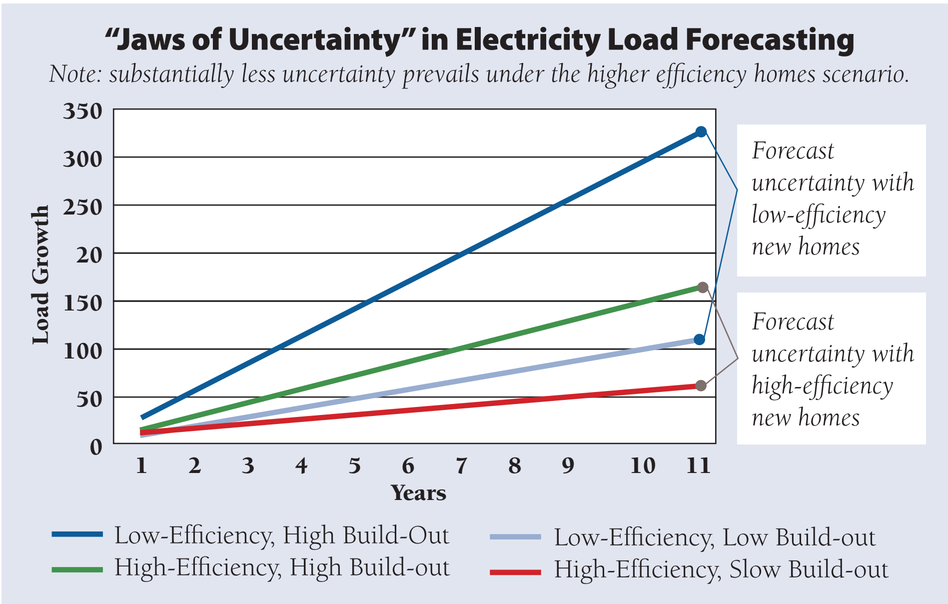
100 Lazar et al, 2011a.

101 Kleen Energy's new 620-MW gas-fired plant was nearly complete when it exploded on February 7, 2010, killing six.

102 Northwest Power and Conservation Council, 2010.

103 Neme et al, 2012. p. iii.

Figure 7



lead time uncertainty and resource development uncertainty will assign additional value to high-reliability, short lead time resources like energy efficiency. The Northwest Power and Conservation Council, for example, found that "risk" added approximately $20/MWh to the value of energy efficiency;[104] Vermont included $2.27/MWh for risk. Some states simply incorporate a percentage adjustment to reflect reduced risk in their efficiency screening.[105] A 2012 assessment by Ceres, analyzing for energy regulators the relative cost and relative risk of supply resource choices, found that energy efficiency provided the lowest overall cost and the lowest overall risk.[106]

In short, inclusion of a value for risk reduction means that more energy efficiency measures and energy efficiency programs will be found to be cost-effective.

4.8. Displacement of Renewable Resource Obligation

Energy efficiency programs reduce the total load, and therefore reduce the amount of renewable energy required to satisfy a typical RPS. For example, in California, with a 33-percent RPS in effect by the year 2020, the acquisition of energy efficiency in effect avoids the necessity of acquiring 67 percent of non-qualifying resources plus 33 percent of qualifying resources.

In some states, the acquisition of energy efficiency can also be used to satisfy the state RPS directly. This may mean displacement not of an "avoided cost" resource, but avoidance of a "premium cost" resource. If this is the case, then the cost analysis should be based on the cost of a renewable resource. It could also use the value of a renewable energy certificate (REC) in areas where RECs are used to determine compliance with an RPS.

4.9. Reduced Credit and Collection Costs

Investments in low-income energy efficiency produce numerous benefits for utilities. The most obvious of these are the same as other measures: production, transmission, and distribution capacity; energy savings; line loss and reserves avoidance; avoidance of environmental costs and environmental damage; and displacement of renewable resource obligations. In addition, however, low-income measures also provide other utility and non-utility benefits. If low-income usage is reduced, and their bills are thus lower, it is likely that the level of non-payment will be diminished, reducing the utility's need to provide for uncollectible accounts, collection expenses, and the like. One recent study pegged these benefits at as much as ten percent of low-income weatherization program costs.[107]

4.10. Demand-Response Induced Price Effect

Investment in energy efficiency can reduce demand for electricity, thereby reducing the market-clearing price for electricity. In the process, the market-clearing price for natural gas may also be reduced. These are called demand-response induced price effects, or DRIPE.

This effect brings savings to all electricity and natural

104 Northwest Power and Conservation Council, 2010. Appendix E.

105 Vermont Public Service Board, 1990.

106 Binz et al, 2012.

107 Washington State University, 2011.

gas consumers in the same market.[108] Even fully regulated utilities that own most of their own generation typically transact some power in the market at the market-clearing price, and are affected by DRIPE.

DRIPE has the effect of making market imperfections more obvious, by substituting lower-cost resources (i.e., energy efficiency) that were not being acquired in the market before market intervention in the form of utility-supported DR programs and energy efficiency investments.[109]

The effect can be quite dramatic. If a one-percent reduction in demand causes a two-percent reduction in the price, then the marginal cost (change in total revenue as a function of quantity) drops almost three times the market-clearing price. The simple example in Table 11 illustrates this effect, using a hypothetical reduction in electricity usage that produces a measured marginal cost that is almost triple the market-clearing price.

Some economists may argue that DRIPE actually reflects a transfer payment – consumers are better off, but producers are worse off. The fact that DRIPE exposes market inefficiency and redirects the economy to more cost-effective products, however, is undeniable. At least some portion of the loss in welfare to producers as a result of DRIPE is a genuine gain in economic efficiency, so is properly included in a full accounting of energy efficiency economic benefits.

4.11. Other Benefits

There is great value to avoidance of power outages and price spikes. In several cases, utilities faced with imminent capacity shortages have implemented "emergency"

Table 11

Example of Demand-Response Induced Price Effects

Demand Before Intervention (MW)	100
Price Before Intervention ($/MWh)	$50
Total Revenue Before Intervention	$5,000
Demand After Intervention (MW)	99
Market Clearing Price After Intervention ($/MWh)	$49
Total Revenue After Intervention	$4,851
Change in Total Revenue ($)	$(149)
Change In Quantity	-1
Marginal Cost ($^{\Delta}$Revenue /$^{\Delta}$Quantity) $/MWh	$149

efficiency programs to reduce load to avoid these situations. During the California power crisis of 2000 and 2001, the cost-effectiveness thresholds for energy efficiency were raised sharply for measures that could be implemented quickly, such as bulk distribution of compact fluorescent light bulbs.

All utility systems experience periods of stress caused by equipment failure, capacity limitations, and unexpected weather events. Intensive energy efficiency deployment reduces the pressure on the grid in such events, giving operators more flexibility in managing their systems.

Following the mortgage and economic crash of 2008, federal stimulus funds were made available for a variety of energy efficiency programs. Preference was given to programs that could be deployed quickly and that used the existing workforce; for example, federal support for low-income weatherization was augmented, and a program for moderate-income households deployed, simultaneously providing energy savings and employment for workers displaced from the hard-hit residential construction industry. The macroeconomic benefits were of equal importance to the energy savings benefits in the design and deployment of these programs.[110]

4.12. Compiling a Combined Marginal Utility System Cost Savings

Based on the PG&E marginal cost study referenced earlier, Table 12 illustrates how composite marginal energy production, transmission, and non-coincident peak distribution capacity cost, plus marginal energy cost, all add up. This is computed for hypothetical and illustrative measures with different load shapes. It is intended to provide a sense of how different measures have different utility system savings characteristics. Note that these figures do not include any provision for CO_2 or other emissions

108 Note that because power and fuel markets are (at least) regional in nature, the majority of DRIPE benefits may accrue to parties other than those in a single state. 109 Schilmoeller, 2011.

109 Schilmoeller, 2011.

110 For a detailed discussion of the economic stimulus benefits of energy efficiency programs, see the testimony of Loper, 2008.

Table 12

Illustrative Energy Efficiency Measures Using the Average Value of PG&E Utility System Marginal Costs [111]

	Unit Cost	Basis	Measure 1 Peak Oriented Air Conditioning	Measure 2 Typical Load Shape Appliances	Measure 3 Daytime Operation Commercial Lighting	Measure 4 Off-Peak Only Street Lighting
Production Capacity	$109.33	CP	$0.062	$0.012	$0.022	$-
Transmission Capacity	$71.13	CP	$0.041	$0.008	$0.014	$-
Distribution Capacity	$108.14	NCP	$0.062	$0.025	$0.031	$0.025
Energy	$.039 - $.059	TOU	$0.049	$0.047	$0.051	$0.040
Total Cost / kWh			**$0.214**	**$0.093**	**$0.118**	**$0.065**

costs, water quality and withdrawal impacts of electric generation, or other "externalities" that are considered in other sections.

Note that coincident peak-oriented measures provide much larger marginal cost savings owing to their avoidance of higher production and transmission marginal costs.

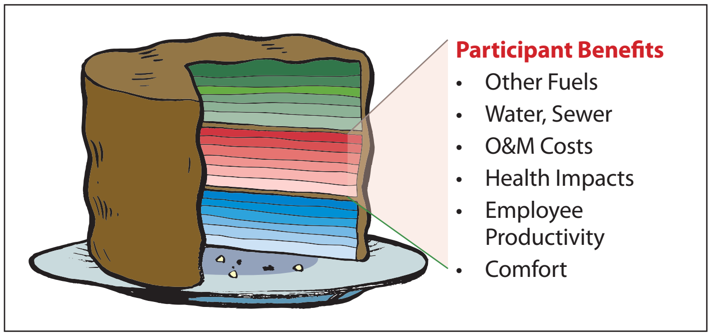
4.13. Summary of Utility System Benefits

While many analysts of energy efficiency program benefits look only at the variable operating costs of the existing utility system, the actual benefits to the system go far beyond this level.

First, there are both peaking benefits and off-peak energy benefits. It is essential to account for these accurately, whether using a "capacity and energy" basis or a "market pricing" approach. Second, there are T&D capacity benefits, which may help avoid very costly system improvements. Third, there are line loss and reserve benefits, which are generally understated even by analysts who do consider them, because analysts often fail to recognize that marginal line losses (and thus capacity benefits) are much greater than average line losses. There are operational savings in system dispatch and maintenance owing to a lower level of system stress. There are savings in direct costs borne by utilities associated with air pollutant emissions, water discharges, and other requirements. The cost of retrofitting existing power plants to meet current and expected future air, water, and waste regulations is very real, and may be avoided through energy efficiency investments. Finally, reducing loads may reduce market-clearing prices for both electricity and for generating fuels, providing benefits to all utilities and fuel users in that market.

111 Derived from PG&E marginal costs and illustrative and hypothetical savings; does not include any consideration of future regulatory requirements or environmental damage costs. The load shape and load factor of these hypothetical loads are strictly illustrative.

5. Other Resource Benefits to Participants



Avoided utility system costs are only a portion of the benefits provided by energy efficiency measures. Participants in energy efficiency programs benefit in numerous ways. One important category of benefits that accrues from energy efficiency are those realized in the form of other resources, for example, water savings, fuel oil savings, propane savings, and even non-energy benefits (discussed in Section 6), including O&M costs of many kinds. It is useful to identify these benefits, in part because it is important to not double count benefits (such as avoided power system costs and lower utility bills, which measure the same savings from two different perspectives). This is not to suggest that utility ratepayers, through their efficiency program charges, should pay for savings of other resources. The point is that the TRC and SCT analyses prepared for review by regulators must include these benefits to enable informed decision-making. Cost-effectiveness determination, appropriate incentive levels for measures, and appropriate program cost budgets are all separate issues.

5.1. Examples of Other Utility Benefits from Energy Efficiency Measures

Two simple illustrations from the residential sector show how extensive other utility benefits can be.

Low-Flow Showerheads. In the United States nearly 45 percent of residential dwelling units have electric water heaters;[112] the installation of a high-efficiency, low-flow showerhead directly reduces the amount of electricity needed to heat the dwelling unit's water. But the benefits of the showerhead go much further:

- The amount of bulk water required by the residential sector goes down, reducing the energy required to pump water at water wells and intake systems;
- The amount of water that is treated to drinking water standards is reduced, thereby also decreasing the amount of water that passes through energy-intensive water treatment plants;
- Chlorine, often used in the water purification and wastewater treatment process, is itself a very energy-intensive product to produce, and less water demand means less chlorine is needed;
- Distribution of water also requires pumping energy, and this is reduced as the quantity of water goes down;
- Less wastewater is released to the sanitary sewer system; which means less wastewater needs to go through wastewater treatment systems with their corresponding extensive pumping and treatment energy; and
- Sewage treatment capacity is very expensive; fewer gallons of sewage translates into deferral of very large capital expenditures by the sewer utility.

Horizontal-Axis Clothes Washers. "H-axis" clothes washers use about half as much water and soap as traditional American agitator washers.[113] They also spin the clothes to about half the moisture level of most older washers, producing significant natural gas or propane energy savings in clothes drying. The water savings benefits are very similar to a low-flow showerhead – from water production through wastewater treatment. But in addition, soap savings alone can pay for the incremental cost of a high-efficiency washer over its lifetime. And the tumble action of these washers is gentler on fabric, so clothes last longer. Many of these benefits accrue only to the participants, whereas others accrue to the water and sewer utility systems from which they receive service.

112 See: www.census.gov/housing/ahs/files/ahs09/, Table 2-5.

113 See High Efficiency Washers: http://laundry.about.com/od/laundryappliances/a/HEWasher.htm

Analysis that looks only at the electric utility system effects will miss many of the benefits.

Whenever energy efficiency measures are considered not cost-effective on a stand-alone, electricity-only basis, it is important to identify any non-electricity benefits and to quantify those that can be measured in order to determine if the measures actually do pass the relevant cost tests.

Many (perhaps most) energy efficiency measures will meet all relevant cost-effectiveness tests without consideration of other resource benefits. And it may not be possible to readily quantify all other resource benefits. However, at a minimum, whenever energy efficiency measures are considered not cost-effective on a stand-alone, electricity-only basis, it is important to identify the non-electricity benefits and quantify those that can be measured in order to determine if the measures actually do pass the TRC or SCT cost tests.

The fact that other resource savings occur also creates opportunities for joint efficiency programs involving electric, natural gas, sewer, and water utilities. While a $50 incentive for a high-efficiency washer from the electric utility may not cause a consumer to choose the better product, for example, if combined with $50 from the water utility and $50 from the sewer utility, participation rates may soar.

5.2. Other Energy Savings (Fuel Oil, Propane, Wood)

A variety of measures that primarily create electricity savings also save other fuels. Some of these are addressed in Section 5.2, where they involve other utilities, such as water, sewer, and natural gas. Sometimes, however, the savings occur in energy sources that are not utility-provided, such as fuel oil, propane, wood, or coal.

Some programs aimed at electric customers will inevitably spill over to other fuels. A home that is partially heated with wood as a supplement to electric heat may be insulated in a utility program, reducing both wood and electricity usage. For instance, a showerhead giveaway program may try to target electric water heating customers, but some of the showerheads will inevitably find their way into showers served by natural gas, propane, or oil. Third, some of the upstream and downstream savings, for example, in water pumping, treatment, or wastewater treatment may also displace fossil fuel consumption.

Finally, some measures are complex, such as upgrades to major industrial processes that use multiple fuels and other resources. A commercial building served by a central chiller may use natural gas for heating. Improved lighting or windows will change the amount of natural gas used for heating. Note that these changes can be positive or negative – improved lighting efficiency will reduce air conditioning needs, but may increase heating energy requirements, for instance.

Identifying all these benefits (and costs) is warranted in almost all cases; quantifying them is essential only when the measures depend on these other resource savings to meet applicable cost-effectiveness tests. Quantification of these other benefits can also be useful in program reporting, utility incentive calculations, and other aspects of program management.

5.3. Reduced Future Energy Bills

Implicit in the previous discussion is the fact that program participants achieve lower energy consumption, and thus pay lower energy bills. However, their reduced consumption helps the utility system avoid marginal costs, while participants' utility rates and bill savings are typically based on average costs. These may be very different. For example, on low-cost utility systems, the marginal cost of new power supplies may be much greater than the average cost of the older resources currently included in rates. We do not include bill savings as a "layer" in the "layer cake" because it is not a component of the SCT; it is primarily relevant in the Participant Cost Test where individual customers compare their costs to install a measure to their own benefits from doing so.

5.4. Other Resource Savings

Individual residential or business consumers installing energy efficiency products that provide water, sewer, solid waste, or other resource savings will enjoy lower bills and costs for those resources. Some of these savings were discussed earlier under utility system savings, but many of them accrue only to individual participants. For instance, a rural home served by a private well with fossil-fuel pumps and on-site septic system will still enjoy savings from lower water pumping energy and lower septic effluent, even though those savings will not accrue to any utility system. These other resource savings should be accounted for as program benefits under the TRC or SCT.

6. Non-Energy Benefits to Participants

Many additional benefits of energy efficiency measures also accrue to participants beyond other fuels or resources. Several are described here.

6.1. O&M Cost Savings

Replacing an incandescent lamp with an LED lamp saves approximately 80 percent of the lighting energy previously used, but beyond these energy savings, the LED lamp also has an average lifetime of 24,000 hours compared with approximately 1,000 hours for an incandescent lamp or approximately 8,000 hours for a compact fluorescent lamp. This means the participant will avoid multiple lamp replacements. In the business sector, where paid staff change light bulbs, this brings a labor savings as well. These O&M cost savings can be very large.

Similarly, replacing an older, less efficient air-conditioner with a new Energy Star® unit will also avoid multiple service calls on the older unit, simply because it is replaced with a new unit. There are substantial societal savings that are directly attributable to the energy efficiency investment, but these maintenance benefits accrue to the participant.

In fact, O&M savings over the life of an energy efficiency measure may be equal to or greater than its energy cost savings. For example, in 2012 the estimated O&M savings from energy efficiency measures installed under Efficiency Vermont's programs equaled two-thirds of total utility system costs, and one-third of total costs.[114]

It is important to identify these savings and quantify them to fully realize the potential, and to help convince participants to install measures that may not appear to be cost-effective on an energy-only basis.

Figure 8

Efficiency Vermont Savings Claims Summary, 2012 [115]

Benefits	$157,300,000	Total Resource Benefits
	$23,600,000	Operations and maintenance savings
	$180,900,000	**Total Benefits**
Minus Costs	$35,900,000	Efficiency Vermont resource acquisition
	$35,600,000	Participant and third-party
	$71,500,000	**Total Costs**
Equals Net Benefit	**$109,400,000**	**Net Lifetime Economic Value to Vermont**

6.2. Participant Health Impacts

When efficiency measures are installed in residences and businesses, improvements to indoor air quality, moisture control, and other environmental health elements often occur. For example, when ceiling insulation is installed, proper attic ventilation is also typically addressed.

In 2008, New Zealand initiated a program to improve the energy use of every low-income household in the country over a four-year period. The evaluation of the initial 40,000 homes treated in the first year showed the dramatic improvements, including:

- A 43-percent reduction in hospital admissions attributable to respiratory ailments;
- A 39-percent reduction in days lost at work; and
- A 23-percent reduction in days lost at school.

The composite evaluation of the program showed that the costs of the program were fully covered by energy savings – but the health benefits were nine times greater than the energy benefits.[116]

114 Efficiency Vermont, 2012. Savings Claim Summary, p. 3.

115 Efficiency Vermont, 2012.

116 Barnard et al, 2011.

Well-designed residential retrofit programs require combustion safety testing, air quality measurement, improved ventilation, humidity and moisture control, and removal of old heating equipment with cracked heat exchangers. All of these will bring benefits similar to those observed in the New Zealand program. This suggests that it might be appropriate to seek health agencies as funding partners for some energy efficiency programs.

6.3. Employee Productivity

Replacing an older air conditioning or lighting system with a newer, more efficient system can also provide employee productivity improvements. Air conditioning is one of the most important labor productivity investments an employer in a hot climate can make, but it consumes a lot of energy.

One major employee complaint in the office environment is glare on computer screens from lighting; replacing such a lighting system with indirect lighting can eliminate this problem and increase employee productivity.

When one utility, the Springfield (OR) Utility Board, sought in 2003 to identify the employee productivity of new high-efficiency lighting systems, it quickly became evident that these benefits could easily exceed the systems' energy benefits. A typical commercial building tenant incurs $5 to $10 per year per square foot for energy costs, but may pay $500 to $1,000 per square foot for employee compensation. As a result, even a one-percent improvement in productivity attributable to better lighting can equal or exceed 100 percent of the energy cost in value to the employer.[117]

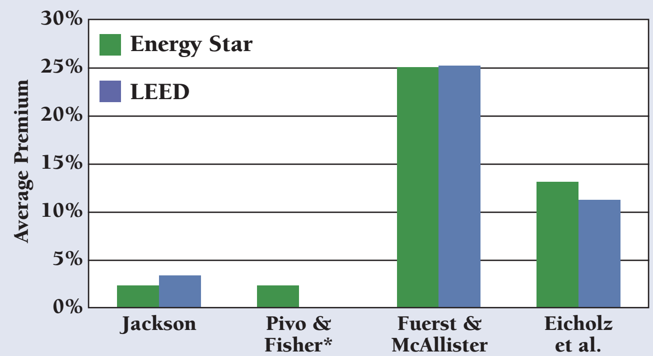
6.4. Property Values

Investments in energy efficiency increase the value of the property where the measures are installed. The property value increase represents the present value of the benefits of energy savings and non-energy benefits. In most cases, counting this is inappropriate in TRC and SCT valuations, because the increase in value is a function of the present value of the economic benefits that the measures provide, and these benefits are accounted for directly. It may be useful to quantify this element, however, when measuring participant costs and benefits, because it will influence the property owner's willingness to invest in energy efficiency. There are circumstances in which a property owner will make an investment knowing they will not receive the full present value, for example, when preparing a home for sale. In this situation, the homeowner will value the present value of their own energy savings, plus the expected higher property value, in deciding whether to invest. If the full present value of energy and non-energy benefits are accounted for in the TRC and SCT, it would be double counting to include property value changes in either test.

As shown in Figure 9, energy efficient buildings clearly carry a price premium of up to 25 percent in the real estate market.[118]

Figure 9

Real Estate Sale Premiums for Green Commercial Buildings



**Study did not include LEED buildings*

Institute for Market Transformation, 2011

6.5. Benefits For Low-Income Consumers

Low-income consumers may derive benefits from energy efficiency programs that customers able to make regular bill payments do not experience. To the extent that energy efficiency programs help avoid curtailment of service, for example, these customers will avoid food spoilage or even more dire health consequences of being without electric service. Although social service agencies may assist with bill payment and restoration of service (see Section 7.4), the customer still suffers from the outage in ways that are never compensated.

117 Aulux, 2011.

118 Leipziger, 2011.

6.6. Comfort

Many energy efficiency measures increase consumer comfort. One of the most obvious of these is the use of air sealing (guided by blower-door tests) to reduce drafts, moisture, mold and rot, and improve heat balance throughout a home.

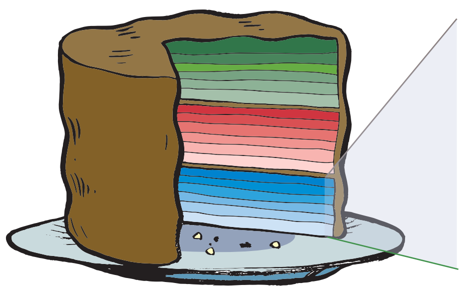
In the New Zealand example cited previously, entire heating systems, windows, and insulation were replaced, resulting in dramatically improved health outcomes for occupants; no doubt those occupants were also more comfortable.

Quantifying comfort is very difficult; but identifying it as a result with a value may allow a regulator to determine a program to be "probably cost-effective" on a TRC or SCT basis if its cost-effectiveness on an energy-only basis is borderline.

6.7. Other

Sections 4.3.1.3 and 4.3.1.4 detailed how electric generators can avoid air pollution compliance costs through energy efficiency. Participants in energy efficiency programs can similarly avoid compliance costs that they themselves would otherwise bear. This is most likely to occur as a result of an energy efficiency measure that allows the customer to reduce on-site fuel combustion (i.e., natural gas, oil, or propane) through building envelope, HVAC, or industrial process improvements. The reduction in on-site fuel combustion in some cases can translate into a reduction in permitting fees, emission fees, or other compliance costs borne by the customer.

7. Societal Non-Energy Benefits



Many of the benefits from energy efficiency investments accrue to the public at large, not just the participants in the program or consumers of the utility system on which the improvements are installed. Conversely, many costs of power supply are not paid by power plant operators or by electric consumers in their power bills, but are very important costs of energy supply that are incurred by others – as externalities.

Among those best recognized are the public health and welfare benefits from lower air pollutant emissions, reductions in GHG emissions that help to slow the pace of climate change, water impacts, and local economic development effects. These and other benefits may add significantly to the overall value of energy efficiency investments.

7.1. Public Health and Welfare Effects

The National Research Council estimates that the costs of health effects from coal-fired power plants averaged 3.2 cents/kWh in 2005, and averaged 0.16 cents/kWh from natural gas plants. However, for approximately 40 specific high-emission coal-fired plants located near population centers, the costs of health effects were calculated to be over 12 cents/kWh.[119] A subsequent work that built on the National Research Council work calculated that externalities related to all aspects of coal extraction and electricity generation averaged 17.84 cents/kWh, with a range of 9.42 to 26.89 cents/kWh.[120]

7.1.1. Air Quality Impacts

To some degree, power plants generally control emissions of some pollutants to the atmosphere; the balance goes up the stack. Some emissions are harmful to human health and welfare as they are emitted; others contribute to chemical reactions in the atmosphere, creating harmful contaminants while airborne.

Fine particle emissions ($PM_{2.5}$) are responsible for the majority of health effects. The constituents of this pollutant vary by geographic location and season, but are dominated by sulfates and nitrates, which are converted from sulfur dioxide (SO_2) and oxides of nitrogen (NO_X) emissions, respectively, and metals like mercury, which travel into the alveoli of human lungs and cause or contribute to many cardiovascular and neurological effects. Where energy efficiency measures facilitate retirement of the dirtiest power plants with the most severe health effects, this benefit can be many times the national average benefit.

Not surprisingly then, the bulk of the public health benefits derive from reductions to $PM_{2.5}$. The San Francisco Bay Area's 2010 Clean Air Plan calculated that 80 percent of the health benefits from control measures in the plan were from $PM_{2.5}$ reductions.[121] A recent EPA report calculated that each ton of reduced emissions from power plants has the following public health benefits: $130,000 to $290,000 for $PM_{2.5}$, $35,000 to $78,000 for SO_2, and

119 National Academies of Science, 2009.

120 Epstein, P.R., et al., 2011.

121 Bay Area Air Quality Management District, 2010 at pp 4-28. Public health benefits were calculated to range from $270 million to $1.5 billion per year, with $770 million per year being the most likely value. Eighty percent of these benefits were derived from reducing $PM_{2.5}$, 20 percent of the benefits were derived from reducing GHG emissions.

Table 13

Effects of Air Pollutants on Human Health, Environment, and Climate[122]			
Pollutant	**Health Effects**	**Environmental Effects**	**Climate Effects**
Particulate matter (PM)	Cardiovascular and lung disease, central nervous system and reproductive system effects, cancer, and premature death	Same effects on animals as humans, affects plant growth and ecosystem processes, damages buildings, reduces visibility	Varies depending on particle size and composition: some lead to net cooling; others lead to warming; can modify rainfall patterns and surface albedo
Ozone (O_3)	Asthma and other lung disease, decreased lung function, and premature death	Damages plant reproduction and growth, decreases crop yields, reduces biodiversity, decreases plant uptake of CO_2	Contributes to warming
NO_X	Liver, lung, spleen and blood effects; lung diseases and infection susceptibility	Precursor of O_3 and PM, increases acidification and eutrophication of soil and water, changes species diversity, damages buildings	Contributes to the formation of O_3 and PM and their climate effects
SO_X	Asthma, reduced lung function, respiratory tract inflammation, headache, general discomfort, and anxiety	Precursor of PM, increases acidification and eutrophication of soil and water, damages vegetation, reduces species diversity, damages buildings	Contributes to the formation of sulfate particles, cooling the atmosphere
Carbon monoxide (CO)	Heart disease, nervous system damage, headaches, dizziness, and fatigue	Same effects on animals as humans	Contributes to the formation of GHGs such as CO_2 and O_3
Arsenic (As)	Cancer, damage to blood, heart, liver, and kidney; may also damage the peripheral nervous system	Highly toxic to wildlife, reduces plant growth and crop yields, persists and bioaccumulates	No specific effects
Cadmium (Cd)	Likely carcinogenic, may damage reproductive and respiratory systems.	Toxic to aquatic life, persists and bioaccumulates	No specific effects
Lead (Pb)	Affects almost every organ and system, premature birth, impairs mental development and growth	Reproductive problems, adverse impacts on terrestrial and aquatic systems, persists and bioaccumulates	No specific effects
Mercury (Hg)	Damages liver, kidneys, digestive, and respiratory systems, brain and neurological damage, and impairs growth	Very toxic to wildlife, persists and bioaccumulates	No specific effects
Nickel (Ni)	Cancer, skin allergies, affects respiratory, immune, and defense systems	Same effects on animals as humans, toxic to aquatic life	No specific effects
Benzene (C_6H_6)	Cancer, leukemia and birth defects, affects central nervous system, blood, and immune system	Damages crops, reproductive systems, toxic to aquatic life, bioaccumulates	Benzene is a GHG contributing to the warming of the atmosphere. It also contributes to the formation of O_3 and secondary organic aerosols, which can act as climate forcers
Benzo-a-pyrene (BaP)	Cancer, irritates eyes, nose, throat, and bronchial tubes	Toxic to aquatic life and birds, bioaccumulates	No specific effects
CO_2	No specific effects at low concentrations	Contributes to plant growth, increases ocean acidification	Contributes to warming

122 European Environment Agency, 2012.

\$5,200 to \$12,000 for NO_X.[123] Furthermore, the EPA's regulatory impact analysis for the Mercury and Air Toxics Standards estimates that for each dollar spent to remove these pollutants, \$3 to \$9 in health-related benefits will be realized, with a value of \$37 to \$90 billion/year.[124]

Energy efficiency programs targeted at homes that use wood heat will likely have very large health benefits for the occupants and the surrounding population. Some of these programs may actually increase electricity consumption, while still meeting the TRC test because of reduced wood heating costs and associated non-energy benefits including health.[125]

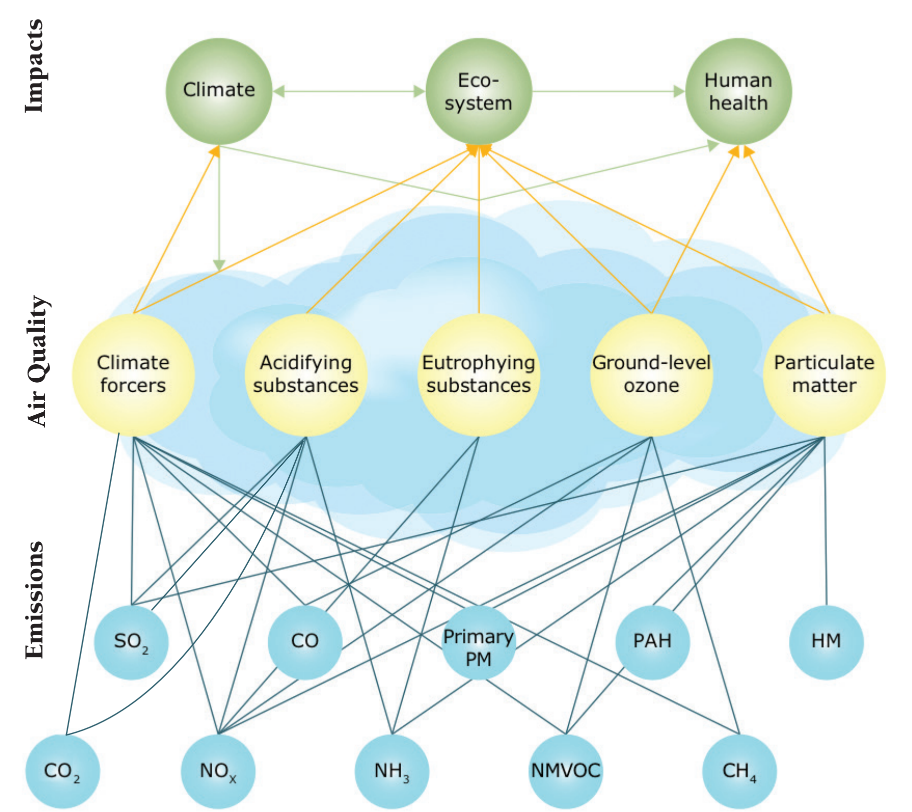
The human health and welfare impacts of air pollution are summarized effectively in Table 13 and Figure 10.

Concerning GHG emissions, utility planning processes should value these emissions at least at the expected value of possible charges that the utility will incur when it receives power from power plants that emit GHGs (e.g., for RGGI allowances in the case of power plants in the northeastern United States). However, this is likely to represent only a portion of the total cost of these emissions. The U.S. Administration recently updated its estimates of the social cost of carbon; they now range depending on the period and discount rate applied from \$11/metric ton of CO_2 to \$221/metric ton, an increase of 50 to 100 percent over the prior values.[127] Federal agencies are required to use these costs in evaluating energy alternatives.

Synapse Energy Economics suggests that states should use a generally applicable marginal abatement cost for CO_2 and recommends its avoided energy supply cost value \$80/short ton as an approximation that represents the general cost of achieving the global climate stabilization goal of 450 ppm.[128] The most rigorous GHG law in the United States, California's AB-32, currently values GHG emissions at approximately \$14/ton.[129]

Figure 10

Major Air Pollutants, Clustered According to Impacts on Human Health, Ecosystems, and the Climate [126]



Note: From left to right, the pollutants above are: carbon dioxide (CO_2) sulfur dioxide (SO_2), nitogen oxides (NO_X), carbon monoxide (CO), ammonia (NH_3), particulate matter (PM, non-methane volatile organic compounds (NMVOC), polycyclic aromatic hydrocarbons (PAH), methane (CH_4), and heavy metals (HM).

123 U.S. EPA, 2013, at Table 5, p. 13. These values are the combined calculation for morbidity and mortality for the power sector.

124 EPA's Regulatory Impact Analysis for the Mercury and Air Toxics Standards. Available at: http://www.epa.gov/mats/health.html

125 Tacoma Power is working with the Puget Sound Clean Air Agency on a project to convert wood heat to ductless heat pumps. The Northwest Power and Conservation Council's Regional Technical Forum is conducting an evaluation to determine if this meets regional cost-effectiveness standards.

126 Modified from European Environment Agency, 2012.

127 Interagency Working Group on Social Cost of Carbon, United States Government, 2013.

128 Synapse Energy Economics, 2011.

129 The \$14 auction value reflects the May 2013 auction results. Results are available at: http://www.arb.ca.gov/cc/capandtrade/auction/auction.htm#august2013

7.1.2. Water Quantity and Quality Impacts

Utilities use massive amounts of water for power plant operations. Although some discharge of pollutants is regulated, virtually all steam electric power plants (i.e., coal and natural gas plants) produce effluent that may adversely affect the biosphere. Water issues are detailed in Section 8.

7.1.3. Coal Ash Ponds and Coal Combustion Residuals

CCRs consist of fly ash, bottom ash, coal slag, and flue gas desulfurization residue. CCRs contain a broad range of metals, for example, arsenic, selenium, cadmium, lead, and mercury, but the concentrations of these are generally low. However, if not properly managed (for example, in lined impoundments), CCRs may cause risk to human health and the environment, and in fact the EPA has documented cases of environmental damage.[130] Although the exact number of active and closed ponds and landfills around the country is unknown, approximately 1,100 ponds and landfills are estimated to be operating currently. As many as half of these may be unlined, and in 2007 the EPA identified 67 cases around the country in which sites used for the disposal of coal combustion waste had been proven to have damaged groundwater or surface water or had been found to be potentially damaging to groundwater or surface water sources.[131] On December 22, 2008, an 84-acre coal ash pond at the Tennessee Valley Authority's Kingston plant near Harriman, TN ruptured, spilling approximately one billion gallons of sludge across the Tennessee countryside. Ameliorating the risk of such contamination and disaster is a societal benefit that energy efficiency can provide.

7.2. Economic Development and Employment Effects

Energy efficiency is typically much less expensive than the energy supply it displaces, so consumers are left with additional disposable income. In addition, it is labor intensive, meaning that the funds invested are spent locally. That disposable income earned implementing energy efficiency is mostly spent locally and circulates in the local economy (subject to relatively rapid leakage) with a multiplier effect.[132]

7.2.1. Employment Impacts

Electricity production is extremely capital-intensive. Furthermore, power plants are sourced globally, and in most parts of the United States, the fuel for electricity production comes from distant, out-of-state or even out-of-country, producing areas.

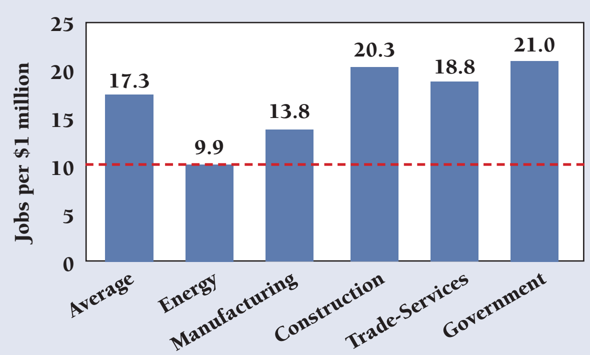
By contrast, energy efficiency involves local skilled workers installing measures that are sourced globally. Energy efficiency typically uses a higher proportion of local labor and generates more jobs per unit of energy delivered than fossil fuel-based electricity production, transmission, and distribution.[133]

Some critics argue that any employment impact is a zero-sum game, with utility workers, gas rig roustabouts, and pipeline companies losing employment as energy efficiency providers employ additional workers. This would be true if the measures had both the same cost and the same mix of capital and labor. But energy efficiency measures are typically much more labor-intensive, and therefore have net positive local employment effects and positive local and global economic impacts.

A 2008 retrospective report analyzing California's 35-year history of energy efficiency concluded that energy efficiency measures have enabled California households to redirect their expenditure toward other goods and services, creating approximately 1.5 million full time equivalent jobs with a total payroll of over $45 billion, driven by well-documented household energy savings of $56 billion from 1972 to 2006. The same efficiency measures resulted in slower

Figure 11

Relative Job Creation For Efficiency vs. Supply[134]



Jobs created through investment in key sectors of the U.S. economy

130 EPA, Coal Combustion Residuals. See: http://www.epa.gov/osw/nonhaz/industrial/special/fossil/ccrs-fs/

131 Landers, 2012.

132 Geller et al, 1992.

133 Wei, 2009.

134 ACEEE, 2012.

growth in energy supply chains, including oil, gas, and electric power. For every new job foregone in these sectors, however, more than 50 new jobs were created across the state's diverse economy.[135] Other assessments of employment impacts are more conservative and/or prospective in their orientation, estimating that California will gain 40,000 new jobs by 2020 from energy efficiency investments.[136, 137]

The same holds true in the northeast owing to the energy efficiency investments made through the RGGI, a regional cap-and-trade program for CO_2 emissions from electric generating units. According to a study by the Analysis Group on the results of the first three years of the program, RGGI's first 13 allowance auctions produced $912 million, the investment of which created value-added economic benefit to the region totaling $1.6 billion and over 16,000 job-years, significant in a region whose civilian work force shrunk during those years.[138]

7.2.2. Economic Development Constraints

As explained in Section 4.3.1.4, when local air quality fails to meet national standards, states must develop SIPs to reduce emissions. SIPs impose compliance costs that wouldn't otherwise apply, not just for electric generators, but across many aspects of society (e.g., vehicle emission testing, industrial emission standards, reformulated gasoline, and so on). Emissions "offset" or netting requirements are also likely to be required, such that manufacturers can't build new factories or expand existing ones unless they find a way to reduce emissions from existing sources. These regulatory compliance costs constrain economic development. The worse the air quality gets, the worse the compliance costs get. To the extent that energy efficiency can avoid air emissions, some of these costs are at least theoretically avoidable, especially if a nonattainment designation can be avoided altogether. In fact, a region with nonattainment caused by emissions from power plants that export their output might find it economically beneficial to help fund energy efficiency in the regions receiving the power.

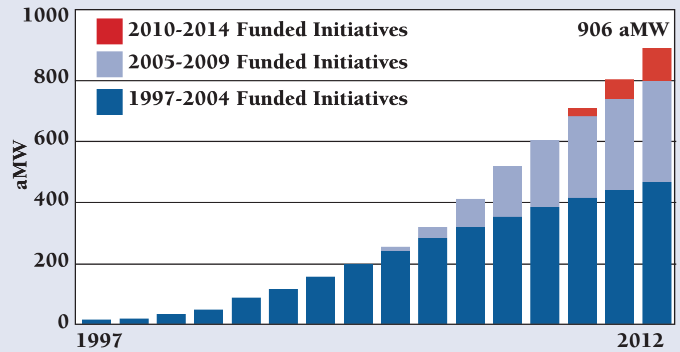
7.2.3. Other Economic Considerations

Studies indicate that the local economic benefit of energy efficiency can be two to four times the value of the energy saved.[139]

Also as a result of energy efficiency, for example, a 2008 study showed that California reduced its energy import dependence, and directed a greater percentage of

Figure 12

Northwest Energy Efficiency Alliance Cumulative Energy Savings, 1997 to 2012[140]



its consumption to in-state, employment-intensive goods and services, whose supply chains also largely reside within the state, thereby creating a "multiplier" effect of job generation. For every job lost in energy supply, the study determined that 50 jobs were created in energy efficiency.[141]

7.3. Societal Risk and Energy Security

In Section 4.7, we discussed how reliance on a mix of small resources reduces risk for the utility system. Experience shows, however, that such risks are not borne by utilities alone. When utility systems are short of supply, or the supply of power is interrupted, adverse impacts echo throughout the economy. "Lost load" is variously estimated to impose a cost on the economy of $2 to $20/kWh,[142]

135 Roland-Holst, 2008.

136 Evaluation, Measurement and Verification Working Group, 2012.

137 Zabin, 2011.

138 Hibbard et al, 2011.

139 Efficiency Vermont 2012 Savings Claim Summary (shown in Section 6.1).

140 Northwest Energy Efficiency Alliance, 2012. Since 1997, the aMW savings associated with NEEA's initiatives are approximately 906 aMW – enough energy to power 660,000 NW homes annually. NEEA estimates a net-levelized lifecycle cost of $.021 per kWh for current investments.

141 Roland-Holst, 2008.

142 Energy Institute at Haas, University of California at Berkeley, 2012.

while the utility system bears only a few percentage points of this in the form of lost revenue.

The Japanese economy suffered severely from the simultaneous shutdown of nuclear capacity in the wake of the Fukushima nuclear disaster. Other regions have suffered from droughts, fuel shortages, and other situations that remove multiple large generating stations from full power simultaneously. Furthermore, lost generation is hardly the only risk; other risks relate to energy security concerns. For example, the U.S. electrical grid is exceedingly vulnerable to those who would do harm. On April 16, 2013, numerous gunshots were fired at critical components of the Metcalf Substation in South San Jose, California.[143] The resulting damage required significant repairs, and perpetrators came very close to knocking out power for much of Silicon Valley for an extended period.

Energy efficiency helps to avoid and minimize these and other risks, which go far beyond the balance sheets of the electricity supply and distribution industries alone. Every business depends on a reliable and affordable supply of electricity. By minimizing electricity demand through energy efficiency, grid operators' margin for error is maximized and risks to reliability are reduced. Similarly, the need for investment in the grid is minimized, reducing costs. Optimizing energy efficiency investment produces benefits for all companies.

7.4. Benefits Unique to Low-Income Energy Efficiency Programs

There are some benefits of low-income energy efficiency programs that are well documented in the literature, but are generally not considered for other efficiency programs.[144] Low-income households have many challenges, and when they cannot afford their energy bill, the adverse impacts may cascade.[145, 146]

7.4.1. Reduction of Effects of Termination of Service

Reducing low-income household energy bills reduces the probability of the household being unable to afford their energy bill, and therefore face termination of service. When customers don't pay their bills, utilities will begin a process that can ultimately lead to disconnecting the customer's electric service. This process requires staff time, notices to the customer, and so forth. In short, it imposes costs on the utility. It can also impose costs on the customer in the form of their time, spoiled food in refrigerators and freezers, and the like.

If and when a customer is disconnected, there will also be provisions that allow for reconnection of service. We Energies, a Wisconsin utility, recently estimated that its costs for each disconnection/reconnection cycle average $64.86.[147] The utility may recoup some or all of its disconnection and reconnection costs from customers as a prerequisite for reconnection, but in any event these are costs that can be avoided by one party or the other if energy efficiency makes energy service more affordable and thereby reduces the frequency of non-payment. Typical disconnect and reconnect fees cover only a portion of the actual cost, so there are normally utility benefits from avoidance of disconnection. To the extent that these disconnection and reconnection costs are borne by non-utility entities (e.g., social service agencies), the cost avoidance should possibly be accounted for as a societal benefit.

7.4.2. Avoidance of Uncollectible Bills for Utilities

Utility rates are designed with a "provision for uncollectible accounts" that recognizes that not all bills will be collected. These costs are normally borne by all other consumers of the utility. To the extent that low-income energy efficiency programs succeed in reducing utility bills, the magnitude of these uncollectible accounts will be reduced, thus providing savings to the utility system and nonparticipants in the form of lower utility bills, and should be accounted for as utility system benefits in Section 4. However, some costs associated with energy service to low-income consumers are borne by payment assistance programs such as the Low-Income Home Energy Assistance Program, a federal tax-funded program. To the extent that non-utility funding is used to support low-income energy services, this is a societal benefit.

143 Hull, 2013.

144 Some would suggest that reducing the costs of terminations of service and uncollectible bills are energy efficiency benefits that rebound to utility systems, not society as a whole. However, low-income consumers typically do not pay the reconnect charge or uncollectible bill; some sort of income assistance program does. Accordingly, these improvements are considered societal benefits here.

145 Washington State University, 2011.

146 Skumatz, 2010.

147 Wisconsin Public Service Commission, 2011. Refer to the "Business Case Cost Analysis."

8. The Electricity/Water Nexus

A profoundly symbiotic relationship exists between water resources and electrical energy. Electric generation places great demands on water; its use is integral in hydroelectric generation, cooling for thermoelectric generation, and scrubbing pollutants from flue gases.[148]

Conversely, water also places great demands on electrical energy. Electricity is vital to providing the water resources necessary for consumption, public health, and economic development, as well as in the extraction, purification, and transportation of water supplies and the treatment of wastewater. The United States moves water great distances with electricity. So there exists a self-compounding "feedback loop": more water requires more energy use, and more energy use requires more water.

We present the water/energy nexus as a separate section because in some regions of the United States (and the world), water supply has reached critical levels and now drives economic decision-making. From Texas to India, competition between power sector needs for water and agricultural, domestic, and industrial demand for water are creating economic crises and technological opportunities. Where substitution of energy efficiency for power supply is possible, this competition for water can be eased. The value of the "water layer" of the layer cake will be particularly important in these regions, and may be an essential guide to policymakers in determining cost-effectiveness criteria and program budgets.

Figure 13

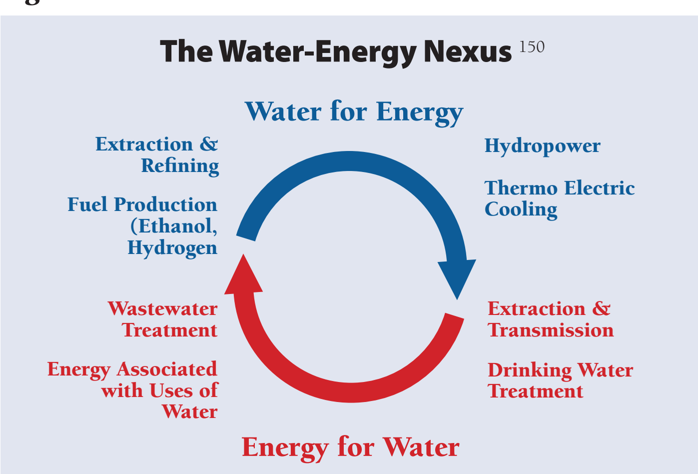


Figure 13 illustrates the interdependency of water and energy, a nexus that has been summarized as "No water, no energy. No energy, no water."[149]

Growing population, warming temperatures, and the increasing frequency and duration of extreme weather events (e.g., severe storms, droughts, and floods) renders the interdependency between water resources and power plants more important and more challenging than ever. Happily, this interdependency extends to many end uses as well, such as domestic hot water. Here, electric energy efficiency measures like low-flow showerheads and horizontal-axis clothes washers can reduce pressure on both electricity supply and water resources simultaneously. Because thermoelectric generation uses so much water, however, even energy efficiency measures that do not conserve water directly provide important water savings indirectly: by reducing demand from power plants, they ease demand on water supplies.

In many regions of the United States water is very scarce, so water savings are very valuable and energy efficiency can provide exceptional benefit. In California, for example, 20 percent of the state's energy consumption is used to gather, purify, and distribute water.[152] The retirement of the Mohave coal plant in Nevada in 2005 freed up 14,000 acre-feet of water from the Colorado River previously used for steam supply, cooling, and coal slurry transport. The value of this water, now managed by the Southern Nevada

148 Colburn et al, 2013. Footnote 23.

149 Colburn et al, 2013. Footnote 24.

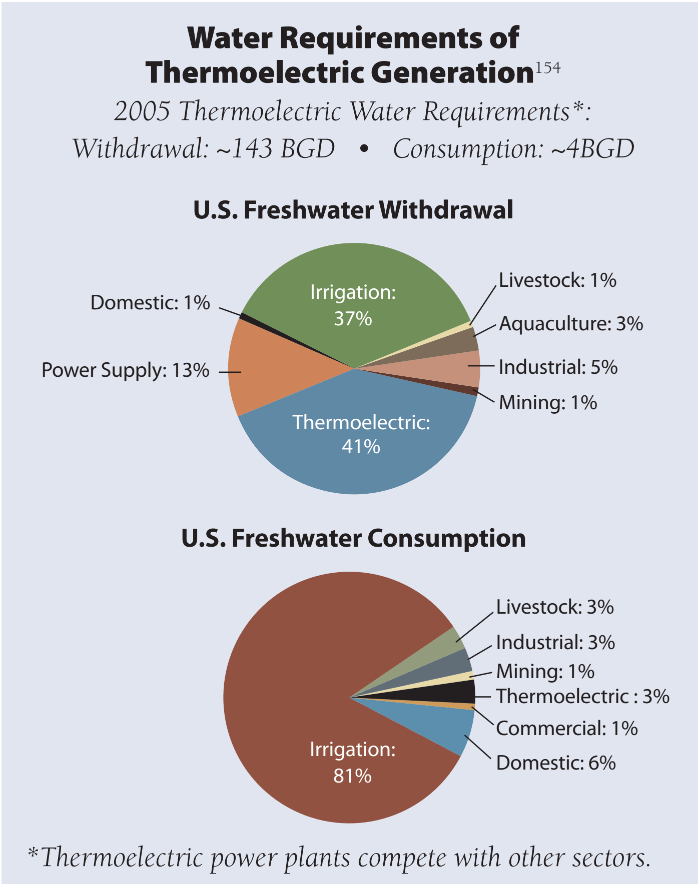
150 For more information see www.voxglobal.com.

151 U.S. DOE, 2006. Page 13.

152 Colburn et al, 2013. Footnote 118.

Water Agency, was so great that it was taken into account in economic analyses comparing energy efficiency and renewable energy to reconstructing the Mohave plant.[153]

Figure 14



8.1. Water Use in the Power Sector

8.1.1. Generation

As shown in Figure 14, steam electric generation is the largest user of water in the United States. Water-cooled thermoelectric power plants withdraw over 140 billion gallons per day from freshwater sources, over 40 percent of all water withdrawn by all sectors. Most of this water is used for cooling and then returned to surface waters. However, approximately 4 billion gallons per day is consumed; approximately ½ gallon of water is lost through evaporation for every kWh of thermoelectric generation.[155]

Conventional coal-fired power plants with recirculating cooling (e.g., cooling towers) typically withdraw between 500 and 600 gallons/MWh of electricity produced, and consume approximately 480 gallons/MWh.[156] As shown in Figure 15, water withdrawal and consumption factors vary greatly, depending primarily on fuel mix and the cooling technologies used.

The full range of the costs of using water is not always reflected in its use by power plants. Few power plants,

153 Southern California Edison, 2005.

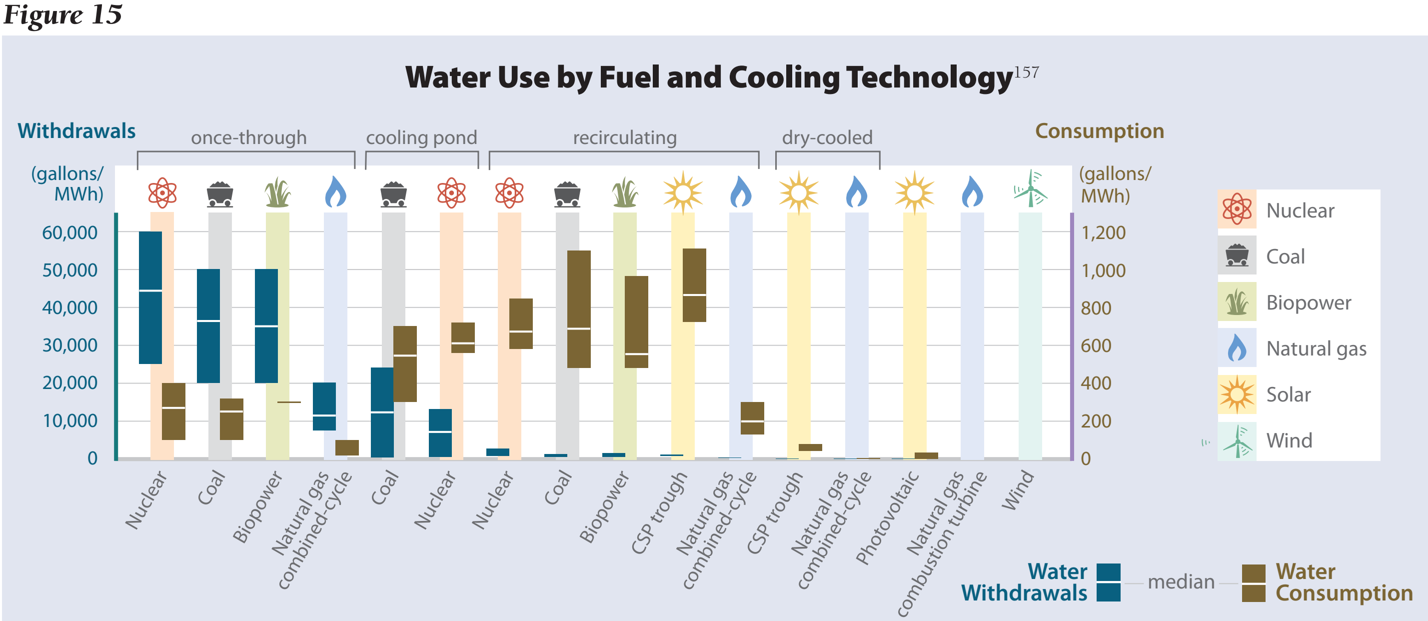
154 Torcellini et al., 2003.

155 NREL, 2002.

156 EPRI, 2008.

157 Union of Concerned Scientists, 2011.

Figure 15



for instance, actually pay fees for the water consumed. Even when they are, however, the costs included may significantly understate the benefit of reduced water usage.

Furthermore, costs are not the only issue at stake. Conventional thermoelectric generation requires a reliable and predictable source of water. When this supply is threatened, system reliability can be compromised. If stream and reservoir levels drop too low as a result of drought, steam electric power plants may not have sufficient water to continue full operation and may have to derate their output or cease operating altogether. Water temperature also plays an important role. As water becomes warmer, its effectiveness as a coolant diminishes. This, along with permit conditions tied to temperature impacts on receiving waters, can also necessitate the derating of thermoelectric generating units. Finally, water supply shortages are not the only risk; too much water can also impact reliability, as flooding causes plants to go off-line.

These concerns are not merely theoretical; each of these circumstances has arisen in the United States in the last decade. This shows that energy efficiency measures can contribute not only to energy savings and non-energy benefits, but also to system reliability.

8.1.2. Upstream (e.g., Extraction and Transportation of Fuels)

The above description of water use in power generation encompasses water requirements on-site. In addition, water is also used upstream for the extraction and processing of fuels for power generation. Coal mining and slurry can consume approximately 35 gallons/kWh.[158] Water requirements for hydraulic fracturing in natural gas production – on the order of 1 million gallons per "frack" (and follow-on treatment of "produced water," fracking's wastewater byproduct) – have also come to the forefront recently, especially in regions such as Colorado that are already water-stressed.

8.2. Power Use in the Water Sector

Electricity is needed to source, extract, desalinate, purify, transport, distribute, and heat water, as well as to collect, transport, and treat wastewater. Nationwide, approximately four percent of the electric power produced is used for water supply and treatment.[159] Non-agricultural power requirements for water vary significantly across regions, depending upon a number of factors such as water sources, topography, and the like. Illustrative power requirements for water supply and wastewater functions in California are shown in Table 14.

Table 14

Energy Requirements for Water Supply and Treatment in California [160]

Water Cycle Segments	kWh/Million gallons Low	kWh/Million gallons High
Supply and Conveyance	0	16,000
Treatment	100	1,500
Distribution	700	1,200
Wastewater Collection and Treatment	1,100	4,600
Wastewater Discharge	0	400
Total	**1,900**	**23,700**
Recycled Water Treatment and Distribution for Non-potable Uses	400	1,200

8.2.1. Production/Extraction

Power requirements for extraction of water depend upon the water source. Pumping from surface water sources requires minimal amounts of energy, whereas pumping from groundwater sources depends upon the depth of the aquifers. If freshwater is supplied through desalination, it can be extremely power-intensive. Desalination plants on average use approximately 15,000 kWh of electricity for every million gallons of fresh water produced.[161]

8.2.2. Transportation

Power requirements for transport of water depend upon a number of factors such as topography, age of infrastructure, and the like. In California, the State Water Project pumps water 400 miles from northern California to cities in southern California; it is the largest single consumer of power in the state, using 5.1 GWh of electricity annually.

158 Sovacool et al., 2009.

159 EPRI, 2002.

160 California Energy Commission, 2005.

161 Cooley et al., 2013.

8.2.3. Wastewater Treatment

Wastewater treatment is also quite power-intensive, consuming as much as 8,300 kWh of electricity for every million gallons of fresh water produced.[162] Most wastewater treatment facilities offer numerous opportunities for energy efficiency improvements.

8.3. Water Impacts of Power Plant Pollution Control

There are hundreds of power plants in need of pollution control retrofits. Many of these retrofits involve fitting scrubbers, baghouses, and other hardware that reduces power plant efficiency and consumes electricity. Ultimately this is measured in the form of a higher heat rate for the power plant, but it also means that less electricity is delivered to the grid per gallon of water withdrawn for power plant operations and cooling. The accompanying text box provides one estimate of the magnitude of this effect.

8.4. Synergies Between Energy and Water Conservation

Many water conservation measures also save energy, and vice-versa. For example, a high-performance showerhead reduces water consumption, but also reduces energy needs for water production, treatment, and water heating, as well as for wastewater management. Similarly, a high-efficiency clothes washer reduces both water and energy requirements. This has been discussed in greater detail in Sections 3 and 4, but is also important to note in this section on the water/energy nexus.

Assuming that 242 GW of scrubbed generation capacity exists and all new pulverized coal plants will be scrubbed, this results in the need for 73 GW of additional power to replace the power lost to parasitic load. If this power loss is replaced with new supercritical pulverized coal plants, freshwater withdrawal would increase by 6 billion gallons per day and consumption would increase by 4.3 billion gallons per day by 2030 compared with water use without carbon capture.[163]

162 Water and Electricity Usage in Southern California, 2009.

163 Carney et al., 2008.

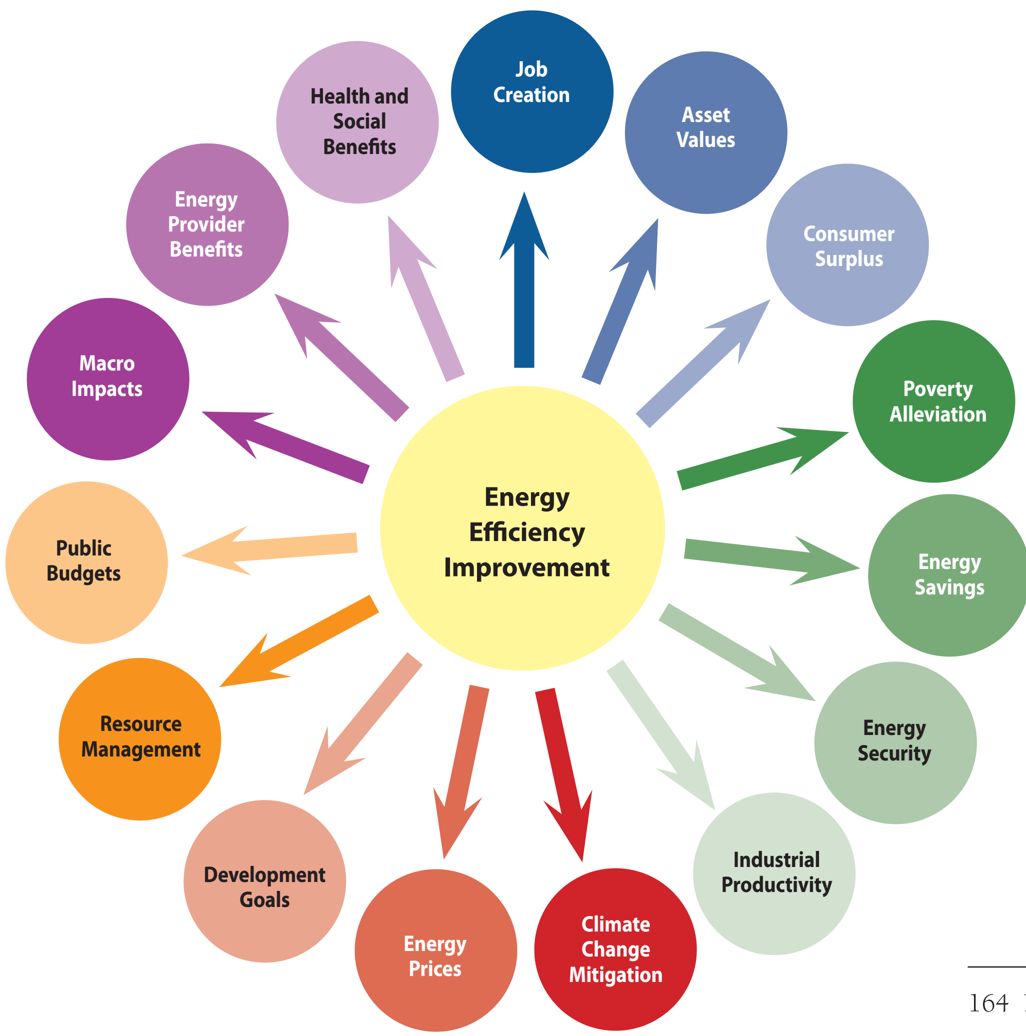
9. Conclusion

It is encouraging that the broad array of benefits provided by energy efficiency – both directly within the electric power industry and wholly external to it – is increasingly understood and acknowledged. Over 30 years of energy efficiency program implementation has yielded concrete, statistically dependable, and often quite remarkable results, and new analytical techniques and metrics are making it possible to discern and quantify previously obscure impacts. Academics, experts, and advocates are distilling a comprehensive gestalt of benefits that energy efficiency provides, and translating it to use in policy venues. The International Energy Agency's continuing work in this direction, illustrated in Figure 16, is but one example of this promising trend.

One policy venue that is crucial to the adoption and penetration of energy efficiency, however, has generally

Figure 16

The Multiple Benefits of Energy Efficiency [164]



164 Ryan et al., 2012.

been slow to appreciate and recognize its multiple benefits. As noted at the beginning of this report, regulators charged with approving the adoption or assessing the performance of energy efficiency measures have typically pursued a conservative path. They have often considered only those benefits that are directly energy-related and can be readily monetized. Other benefits have typically not been considered, despite clear evidence of the magnitude of these benefits to society.

Any energy efficiency benefits that are not considered are implicitly valued at zero, and this report asserts that zero is almost certainly an incorrect valuation in every case.

Regulators have been hindered, however, by a scarcity of concrete examples – and even fewer applicable regulatory tools – to facilitate the inclusion and estimation of previously unrecognized, often difficult to quantify energy efficiency benefits. This report offers a first step toward enumerating, characterizing, quantifying, and where possible, providing case histories of energy efficiency benefits. It provides explanations, examples, and precedents for regulators to apply in their own dockets and deliberations.

Vermont's experience at assigning value to a broad array of energy efficiency benefits provides not only a good example; it also suggests an apt conclusion:

> *"Efficiency continued to be an excellent value compared to the costs of other sources of energy. In 2010, Efficiency Vermont delivered energy efficiency at 4.0 cents per kWh. Taking into account participating customers' additional costs and savings, the levelized net resource cost of saved electric energy in 2010 was 1.9 cents per kWh. Comparable electric supply in 2010 cost 10.8 cents per kWh. On a statewide basis, this differential adds up to significant savings for Vermont homes and businesses. Vermont utilities would have had to pay an estimated $125.1 million over the lifetime of the measures to generate or purchase electricity if these 2010 efficiency investments had not been made."*[165]

It is noteworthy that this conclusion reflects energy efficiency and electric supply costs calculated before recognizing the value of additional energy efficiency benefits that Vermont calculated, let alone the value of several other energy efficiency benefits that were not included in Vermont's assessment. It is further noteworthy that Vermont's performance since 2010 indicates even greater benefits at lower net costs.

Over the long term, society will pay higher costs whenever it pursues inefficient utilization of resources. Least-cost solutions almost always include energy efficiency. Incorporating energy efficiency reduces costs, impacts, and risks, and the sound use of energy is promoted. In short, conscious, concerted consideration of all energy efficiency benefits in regulator decision-making enhances the potential for optimal economic, social, and environmental outcomes.

165 Efficiency Vermont Annual Report 2010, p. 3. The Efficiency Vermont cost divided by the energy savings produces the higher figure. The lower figure is derived by first adding up all costs (including those paid by program participants and third parties), then netting out the present value of non-electricity benefits, and dividing that result by the electricity savings to derive a "net" cost of electricity savings. Because the non-electricity savings nearly equaled the total costs, the net cost attributable to electricity was only 1.9 cents/kWh.

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