The Technical, Economic, and Achievable Potential for Energy Efficiency in the United States: A Meta-Analysis of Recent Studies

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ABSTRACT

In recent years, eleven studies have been conducted on the technical, economic, and/or achievable potential for energy efficiency in the United States. These studies covered many regions (e.g., California, Massachusetts, New York, Oregon, Utah, Vermont, Washington, the Southwest, and the United States as a whole), sectors (residential, commercial, and sometimes industrial), energy types (electricity and/or natural gas), and timeframes (e.g., 5, 10, and 20 years). In this paper we summarize the results of these different studies and then compare and contrast them to tease out overarching findings. The 11 recent studies examined in this paper show that very substantial technical, economic, and achievable energy efficiency potential remains available in the United States. Across all sectors, these studies show a median technical potential of 33% for electricity and 40% for gas, and median economic potentials for electricity and gas of 20% and 22%, respectively. The median achievable potential is 24% for electricity (an average of 1.2% per year) and 9% for gas (an average of 0.5% per year). We compare the achievable potential findings to recent-year actual savings from portfolios of electric and natural gas efficiency programs in leading states and find substantial consistency, and conclude with several recommendations for future energy efficiency potential work.

Introduction

In the 1980s and early 1990s, states and utilities conducted a variety of studies conducted to estimate the opportunity for energy savings in their territories. These studies helped to quantify the size of the energy efficiency resource and to identify the major opportunities for energy savings. This information in turn was used to decide the magnitude of energy efficiency programs and the particular targets of these programs.

For example, ACEEE conducted a series of energy efficiency potential studies for New York State over the 1989–1994 period. In 1989, ACEEE examined the technical and economic potential for electricity conservation in New York State and found that the technical potential for efficiency savings was 38% across the combined residential and commercial sectors. *Technical potential* includes all measures examined, without regard to measure economics. This same study found an *economic savings potential* of 22–34%, depending on the economic perspective taken, with the lowest potential just considering utility economics (i.e., electricity savings valued at the utility avoided cost and utility discount rates) and the highest potential considering societal economics (avoided costs and benefits evaluated using a societal discount rate). As was typical for studies of this period, this study found the highest savings potential in the commercial sector and the lowest in the industrial sector (Miller, Eto, and Geller 1989). In a follow-up study, ACEEE found an *achievable conservation potential* of 27% for New York State by analyzing the savings that could be achieved through normal market forces, new state building codes, equipment efficiency, and utility energy efficiency programs. All of these programs and policies passed the cost-effectiveness tests then used in New York State (Nadel and Tress 1990). And in 1994, ACEEE examined the technical and economic savings potential for natural gas in New York State, finding an economic potential of 21–45% in the residential sector and 17–23% in the commercial sector (the industrial sector was not examined). The range of savings reflects different sections of the state and varying assumptions regarding avoided gas costs and the administrative costs of energy efficiency programs (Nadel et al. 1994)

During the second half of the 1990s, few of these studies were conducted because the focus was on the restructuring of the electricity and natural gas industries, and as a result many utilities and states cut funding for "non-essential" items (including energy efficiency programs and research) in order to better prepare for restructuring. Still, as part of restructuring, many states established "public benefit funds" to fund energy efficiency and other programs that were traditionally included in utility rates. Other states and utilities continued (often scaled-back) programs funded through rates.

By 2000, interest in energy efficiency programs had "turned the corner" and funding for efficiency programs began to increase relative to the late 1990s (York and Kushler 2002). A growing number of states established public benefit funds, and growing concerns about electric system reliability in the East, Midwest, and West during 2000 and 2001 also contributed to increased interest in energy efficiency programs. Due in part to this growing interest in efficiency, as well as to a desire to update efficiency potential studies that were nearly a decade old, quite a few states and utilities have conducted efficiency potential studies since 2000. This paper summarizes the findings of these different studies and attempts to tease out patterns that emerge across the different studies.

For this paper, we examine a total of 11 different studies including ones examining the United States as a whole (Interlaboratory Working Group 2000) and studies on California (Coito and Rufo 2003, Rufo and Coito 2002), Massachusetts (RLW 2001), New York (Optimal Energy et al. 2003a), Oregon (Ecotope 2003a, 2003b), Southwestern states (SWEEP 2002), Utah (GDS 2004), Vermont (Optimal Energy, Inc. 2003b), and portions of Washington state (Puget Sound Energy). In addition, studies are now underway in Connecticut, Georgia, and Wisconsin but were not ready in time for inclusion in this paper.

In the balance of this paper, we review and analyze the results of these different studies. We start by summarizing the range of savings potential estimates, first for all studies and then differentiating among technical, economic, and achievable savings potential. We then dig deeper by examining results by sector (residential, commercial, and industrial) and end-use and also by examining savings per year in order to adjust for different study timeframes. These discussions lay the groundwork for a section in which we try to explain why the different studies reach different conclusions. In order to put these studies in context, we then compare results from these studies with savings that have been achieved in the field in recent years. Finally, we draw some summary conclusions and make recommendations for further work.

Analysis of Recent Studies

Overall Savings

Savings potential across the 11 studies ranges from a 5% achievable savings potential for natural gas throughout the United Stated over a 10-year period (Interlaboratory Working Group 2000) to a technical savings potential of 40% or more in studies on Oregon and Washington

State (Ecotope 2003b, Puget Sound Energy 2003). In some states and sectors, the technical savings potential is as high as 69%. However, to make sense of this variation, it is useful to look separately at the type of savings potential (technical, economic, and achievable), the energy form involved (electricity or natural gas), the sector, and the number of years in which savings can be achieved.

Technical, Economic, and Achievable Potential

Table 1 and Figure 1 summarize the results of the 11 different studies including estimates of the technical, economic, and achievable savings potential. Only a few studies included all three potentials—many include one or two types of potential. Many of these studies also included multiple estimates of potential with estimates varying by scenario, time period, and sector examined. For purposes of this initial comparison, we only include composite estimates across the maximum number of sectors incorporated, the longest time period, and the more aggressive scenarios. We discuss other estimates in subsequent sections of this paper.

Table 1. Summary of Results from Recent Technical, Economic, and Achievable Energy Savings Potential Studies

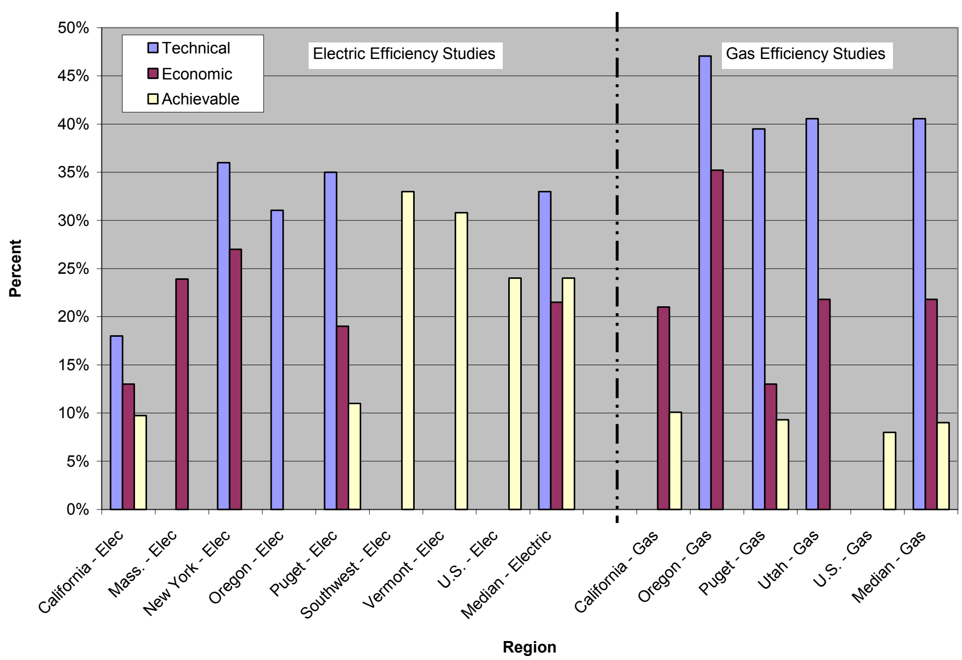
				Potential (%)		
Region	**Year**	**Fuel**	**# Years**	**Technical**	**Economic**	**Achievable**
California	2003	Electric	10	18%	13%	10%
Massachusetts	2001	Electric	5		24%	
New York	2003	Electric	20	36%	27%	
Oregon	2003	Electric	10	31%		
Puget	2003	Electric	20	35%	19%	11%
Southwest	2002	Electric	17			33%
Vermont	2003	Electric	10			31%
U.S.	2000	Electric	20			24%
Median		Electric		33%	21.5%	24%
California	2003	Gas	10		21%	10%
Oregon	2003	Gas	10	47%	35%	
Puget	2003	Gas	20	40%	13%	9%
Utah	2004	Gas	10	41%	22%	
U.S.	2000	Gas	20			8%
Median		Gas		41%	22%	9%

Note: This table only includes the longest time periods and more aggressive scenarios covered in each study.

The highest savings potentials will generally be technical potentials, since technical potential is not constrained by economics or the practical realities of getting homeowners and businesses to actually undertake energy-saving actions and investments. Theoretically, the technical savings potential can approach 100%, since there are always additional improvements that can be made that are uneconomic. However, most technical potential studies try to include only measures they think may be cost-effective, and thus the technical potential is generally way below 100%. In other words, while the different studies generally agree on how technical potential is defined, they differ in the depth of analysis, with many studies not including every possible savings opportunity. Across the different studies, the technical potential for electricity savings ranges from 18–36% with a median of 33% (we focus on median and not mean because mean can be heavily influenced by outliers). Most of the estimates are in the 31–36% range, except for the California study that only looked at technologies ready for widespread promotion today and generally constrained the technical potential to equipment that needs to be replaced over the next 10 years. For natural gas, technical savings potential ranges from 38–47% with a median of 40%. These estimates do not include the industrial sector.

The economic savings potential will always be less than the technical potential because economic potential excludes measures that are not cost-effective, where cost-effective typically is based on lifecycle economics assuming specific energy prices and discount rates. Some studies viewed cost-effectiveness from the customers' perspective, while others used a societal perspective. For electricity, the economic potential ranges from 13–27% with a median of 21.5%. Again, the California study provided the lowest estimate. For natural gas, the economic potential ranges from 13–35% with a median of 20%. Most of the estimates range from 13–21%, with one outlier at 35%. This study, which covered Oregon, found a very high economic savings potential in the residential sector (54%), which substantially raises the average across the two sectors examined. Based on the median figures reported, economic savings potential is about two-thirds of the technical potential for electricity, and half of the technical potential for natural gas.

Figure 1. Summary of Results from 11 Recent Energy Efficiency Potential Studies



Achievable potential is always less than economic potential since achievable potential is constrained by the rate at which homes and businesses will actually adopt energy-saving technologies and practices. Only three studies estimated both economic and achievable potential, and the achievable potential averaged about 60% of the economic potential. However, several studies estimated achievable potential but not economic potential, and thus median results for achievable and economic potential cannot be directly compared.

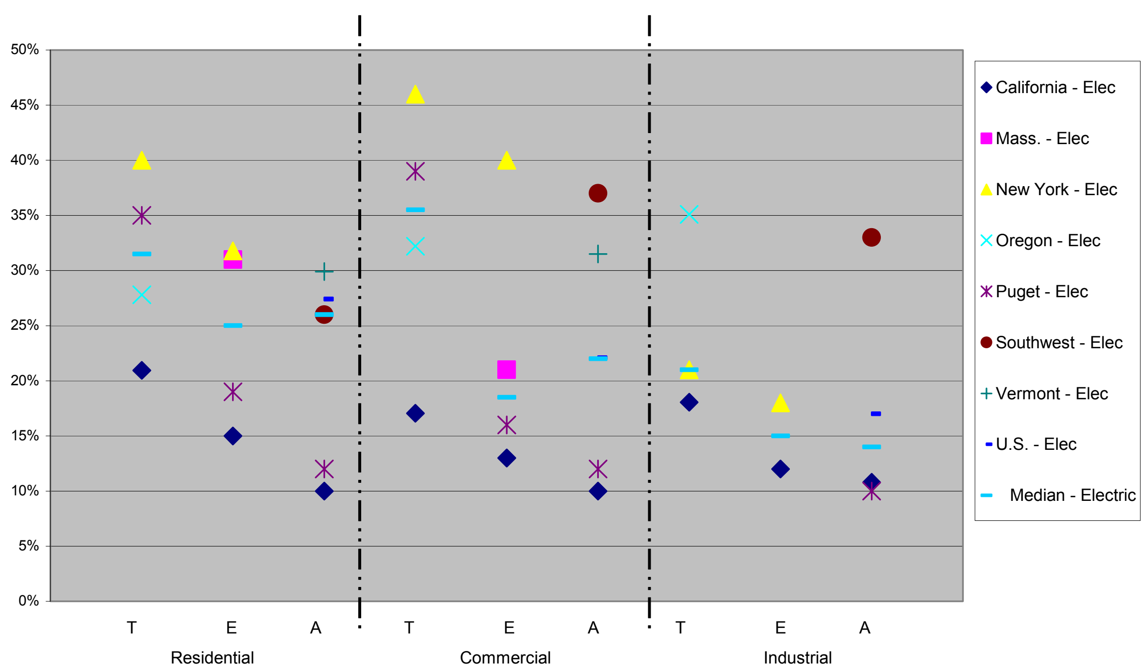
For electricity, achievable potential ranges from 10–33%, including two studies estimating 10–11%, two estimating 31–33%, and one estimating 24% (this last estimate is the median). The low estimates are the California study discussed above and a study by Puget Sound Energy that appears to have included high measure costs and eliminated many measures for poor economics. The two high estimates (for Vermont and the Southwest) are for very aggressive program and policy efforts. For example, the Vermont study labeled its estimate "maximum achievable" and stated that this "would result if the state made a concerted, sustained campaign involving highly aggressive strategies" including "sustained marketing to consumers and upstream suppliers;" "generous financial incentives covering full technology costs;" "comprehensive technical and information services to all market participants;" and "complete customer service delivery."

For natural gas, the achievable potential estimates ranges from 8–10% with a median of 10%. These include the California and Puget Sound Energy studies that previously were cited as having relatively low achievable potential estimates for electricity.

Differences by Sector

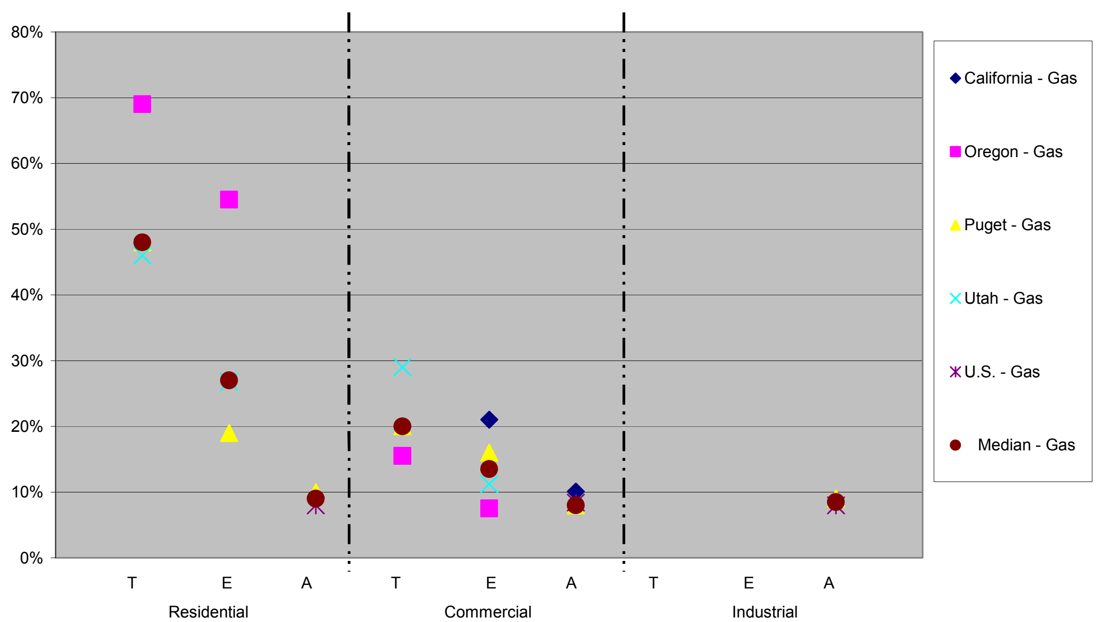
Figures 2 and 3 summarize the savings potentials across the three sectors. Figure 2 covers electricity and Figure 3 natural gas. In these figures we graph the technical, economic, and achievable potential savings estimates for the residential, commercial, and industrial sectors and also display the median for each sector and type of potential. For purposes of this discussion, we concentrate on these medians and not the results of individual studies.

Figure 2. Summary of Electricity Savings Potential by Sector



For electricity, the median study found similar potential savings on a percentage basis for the residential and commercial sectors, and somewhat lower potential in the industrial sector. Across the studies examined the median technical potential is 32% for the residential sector, 36% for the commercial sector, and only 21% for the industrial sector. The median achievable potentials are 26%, 22%, and 14%, respectively. The median economic potential is slightly lower than the median achievable potential because several studies provided achievable potential but not economic potential.

Figure 3. Summary of Natural Gas Savings Potential by Sector

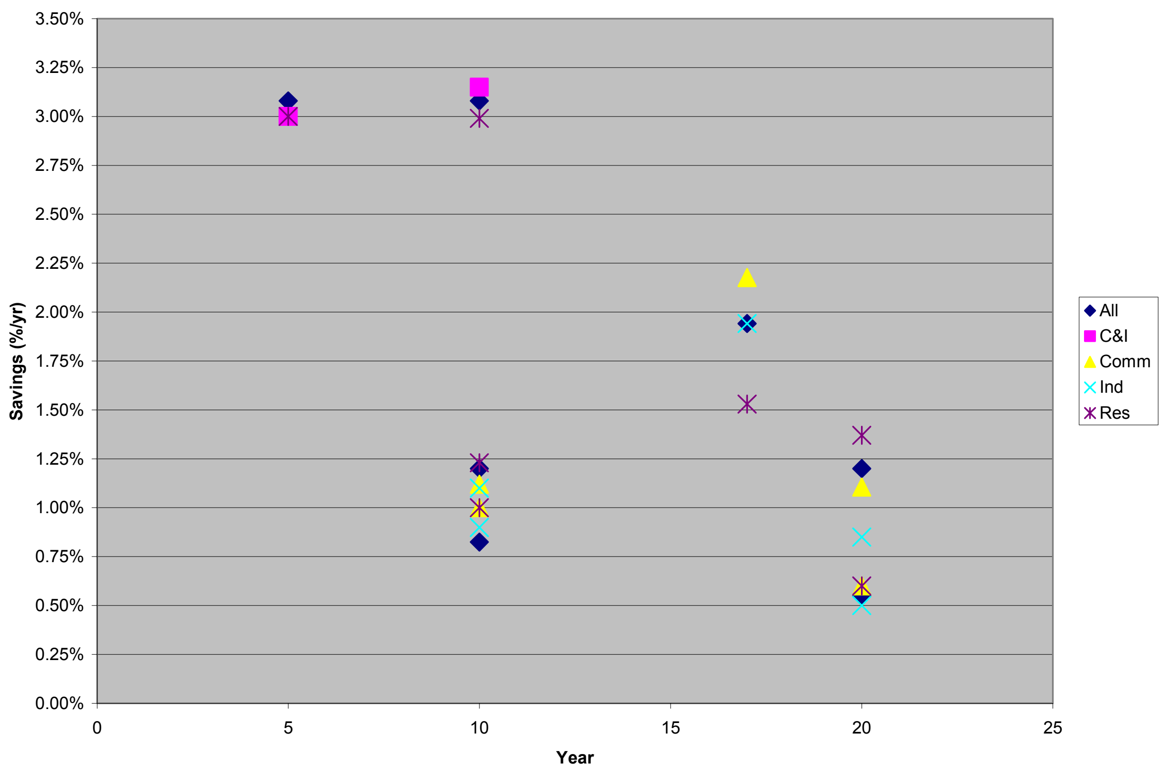


For natural gas, savings potentials appear to be highest in the residential sector and lower in the commercial sector. The median technical potential is 48% in the residential sector and 20% in the commercial sector. For the economic potential, the medians are 27% and 14% savings, respectively, while for achievable these drop to 9% in the residential sector and 8% in the commercial sector. However, the large difference between the 27% economic potential and 9% achievable potential in the residential sector is primarily due to the fact that only two of the more conservative studies examined achievable potential while the highest estimate of technical and economic potential did not include an achievable potential estimate. There is only one recent study on the industrial sector, which found savings similar to those available in the commercial sector (achievable potential of 9%).

Savings per Year

The various studies examined differing time periods, which can affect the savings estimates. Economic and achievable potential estimates likely are particularly sensitive to the time period of the analysis since these potentials are affected by the annual rate of new construction and equipment replacement. Figure 4 presents the achievable potential for electricity savings in terms of savings per year. Across all of the studies, the overall median achievable potential savings is 1.2% per year, with similar medians for each of the sectors. However, another interesting finding is that achievable potential per year is often lower for long-term studies (e.g., 20 years) than for shorter-term studies. Based on discussions with the authors of several of the studies, this appears to primarily be due to the fact that existing technologies can be heavily adopted over the first decade, and that the new technologies and practices that past experience would lead us to anticipate would emerge during the second decade are not included in most potential studies. As new energy-saving technologies and practices are developed, they will increase potential savings in the out-years. Support for this view is provided by the fact that studies of potential over the 2000–2004 period are generally finding similar potentials to studies from the 1990s. Some technologies in the 1990s studies are now common practice, but have been replaced by new opportunities. Potential studies have difficultly looking at technologies more than a decade into the future, so this drop-off in the second decade is to be expected. Few of the studies provide information on savings in financial terms, so we cannot compare studies on this basis.

Figure 4. Achievable Electricity Potential per Year as a Function of Study Timeframe



For natural gas, there are far fewer data points and, as discussed above, the achievable potential studies are fairly conservative due in part to more limited program experience. As a result, the median savings potential is about 0.5% per year over both 10- and 20-year periods.

Savings by End-Use

As part of our analysis, we also looked at potential savings for different commercial and residential end-uses such as lighting, cooling, and heating. The estimates available are primarily for economic potential. ACEEE compiled the various estimates of economic potential by end-use for each study, identified the median savings per year estimate for each end-use, and compared these medians to the median savings per year for each sector. The result is a ratio of median end-use savings to median sector savings. End-uses with a ratio greater than one have more savings potential than the sector average and visa versa. Only limited data are available, so these estimates should be considered very approximate. The resulting ratios are summarized in Table 2.

Table 2. Ratio of End-Use Savings to Sector Savings: Median Values from Economic Potential Studies

Sector	Fuel	End-Use	Multiplier
Residential	Gas	Space heating	1.0
		Water heating	1.1
		Other	0.6
Residential	Electricity	Space heating	0.8
		Space cooling	1.2
		Water heating	1.0
		Appliances & other	0.9
Commercial	Gas	Space heating	0.9
		Water heating	1.4
		Cooking	0.6
		Other	0.6
Commercial	Electricity	Space heating	0.2
		Space cooling	1.0
		Ventilation	0.9
		Water heating	0.6
		Lighting	1.2
		Cooking	0.5
		Refrigeration	0.8
		Office equipment	1.1
		Other	0.5

Source: Elliott et al. 2003

A similar analysis for the industrial sector would be misleading because the end-use opportunities are highly industry specific, and ACEEE's industrial sector analyses have found dramatic variations in industry mix by state.

Explanations for Differences among the Studies

In the sections above, several reasons are discussed for differences among studies. For example, the California electricity saving study showed lower technical and economic potential than many of the other studies because it examined a limited number of measures and often limited the technical potential to equipment that would be replaced over the next 10 years. Likewise, the Puget study appears to have found a low achievable potential due to relatively high measure costs. On the other hand, the Vermont and Southwest studies found very high achievable potential because they assumed very aggressive program and policy intervention, more aggressive than the other studies seem to assume. In general, the estimates of achievable potential for natural gas are low relative to the economic gas potential and the achievable electric potential. But this finding is based on only three studies, two of which as noted above were fairly conservative, and the third (the U.S.-wide study) used fairly low avoided natural gas prices (it was conducted in 2000, before gas prices climbed). Also, the experience with programs to promote natural gas efficiency is more limited than experience with electric efficiency (Kushler, York, and Witte 2003), perhaps leading to more conservative estimates of achievable potential. Additional analysis on the achievable potential for natural gas savings would be useful. Furthermore, as discussed above, potential per year tends to be lower in long-term studies than in short-term studies. Additional work would be helpful to better understand technology trends in order to better characterize potential over the long term.

Thus, differences in findings among studies can be attributed to several factors including:

- The methodology employed (e.g., limiting technical and economic potential to natural turnover as occurred for many measures in the California study);
- The measures included (e.g., California only included measures that were ready for widespread promotion in 2001);
- The number of years included in the analysis (particularly a factor for estimating the achievable potential);
- Estimates of measure costs (this appears to have reduced the economic potential in the Puget study); and
- The avoided costs assumed (a factor in the U.S.-wide study).

Comparison of Studies to Recent DSM Results

As discussed above, the studies surveyed in this paper found an electricity achievable savings potential of about 1.2% savings per year of program implementation and a gas achievable savings potential of about 0.5% savings per year. A natural question is whether savings of these magnitudes can be achieved in practice. Therefore, as a check on these studies, we compared the annual achievable savings figures to actual savings achieved by leading utility programs. The most aggressive example of what can be achieved in practice is the experience in California in 2001. California achieved 6% electricity savings in 2001, of which about one-third (i.e., 2% per year) was in hardware improvements (Global Energy Partners 2003). On a more regular basis, a 1995 analysis by ACEEE found that the leading utilities were achieving energy savings of 0.5 to 1.0% per year (Nadel and Geller 1995), approaching the estimates above. Similar savings have been achieved in recent years, as shown in Table 3. Regarding natural gas, leading gas efficiency programs are run by Vermont Gas and Xcel Minnesota. They have each achieved approximately 0.5% savings per year respectively in recent years (Kushler, York, and Witte 2003; Xcel Energy 2003), in line with the achievable potential estimates discussed above. These savings have all been achieved in areas with moderate growth in electricity and natural gas use. In areas with rapid growth, due to the high rate of new construction, achieving additional savings may be possible.

Table 3. Electricity Savings Achieved Per Year in Leading States

	Year	Annual Incremental GWh Savings	kWh Sales	Savings/Year (%)
California	2001	4,760	239,654	2.0%
	2002	1,463	235,249	0.6%
Connecticut	2001	314	30,000	1.0%
	2002	246	31,000	0.8%
Massachusetts	2000	273	51,773	0.5%
	2001	309	52,092	0.6%
Rhode Island	2001	61	7,341	0.8%
	2002	51	7,516	0.7%
Vermont (Efficiency VT only)	2001	37	5,051	0.7%
	2002	41	5,077	0.8%
	2003	54	5,127	1.1%

Source: Data provided to ACEEE by officials in each state.

Conclusions

The 11 recent studies examined in this paper show that a very substantial technical, economic, and achievable energy efficiency potential remains available in the United States. Across all sectors, these studies show a median technical potential of 33% for electricity and 40% for gas, and median economic potentials for electricity and gas of 20% and 21.5%, respectively. The median achievable potential is 24% for electricity (an average of about 1.2% per year) and 9% for gas (an average of 0.5% per year). However, only a few studies examined achievable potential for gas so additional analysis is needed in this area.

The opportunity for electric savings is highest in the residential and commercial sectors and somewhat lower in the industrial sector. The opportunity for gas savings is highest in the residential sector and lower in the commercial and industrial sectors, although there are very few data points on industrial gas efficiency potential.

A review of the most successful state and utility energy efficiency programs shows that savings of these magnitudes can be achieved in practice (although there are only a few examples of electricity savings above 1% per year). In general, the savings potentials found in these studies tend to be similar to the savings potentials found in studies from the 1990s, despite the fact that many measures included in the 1990s studies such as T8 lamps and electronic ballasts are now widely implemented. What has happened is that many new measures have been developed (e.g., "super T8 lamps" and high-efficiency packaged commercial refrigeration equipment) that have replaced the measures that have been implemented over the past decade.

Recommendations

The results of the studies profiled in this paper show general trends regarding the efficiency potential. These studies can be a useful guide to the development of programs and policies that seek to capture this efficiency potential. However, only a few studies examined the achievable potential for natural gas savings, and the technical and economic potential for industrial gas savings. We recommend that additional studies be conducted in these areas. Additional work is also needed to better understand how development trends for technologies and practices will affect the long-term savings potential. This should include work on understanding technology development, as well as work to better capture the emerging trend to save energy by optimizing systems, such as motor systems or entire new buildings. We also recommend that potential studies be repeated periodically—approximately every decade—in order to identify the best opportunities for the subsequent decade.

References

Coito, Fred and Mike Rufo. 2003. *California Statewide Commercial Sector Natural Gas Energy Efficiency Potential Study.* Vol. 1 of 2. Study ID #SW061. Prepared for Pacific Gas & Electric Company. Oakland, Calif.: KEMA-XENERGY, Inc.

Ecotope, Inc. 2003a. *Energy Efficiency and Conservation Measure Resource Assessment for the Residential, Commercial, Industrial and Agricultural Sectors.* Prepared for the Energy Trust of Oregon, Inc. Seattle, Wash.: Ecotope, Inc.

———. 2003b. *Natural Gas Efficiency and Conservation Measure Resource Assessment for the Residential and Commercial Sectors.* Prepared for the Energy Trust of Oregon, Inc. Seattle, Wash.: Ecotope, Inc.

Elliott, R. Neal, Anna Monis Shipley, Steven Nadel, and Elizabeth Brown. 2003. *Natural Gas Price Effects of Energy Efficiency and Renewable Energy Practices and Policies.* Washington, D.C.: American Council for an Energy-Efficient Economy.

[GDS] GDS Associates, Inc. 2004. *The Maximum Achievable Cost Effective Potential for Gas DSM in Utah.* Draft. Prepared for the Utah Natural Gas DSM Advisory Group. Marietta, Ga.: GDS Associates, Inc.

Global Energy Partners. 2003. *California Summary Study of 2001 Energy Efficiency Programs.* Final Report. Lafayette, Calif.: Global Energy Partners.

Interlaboratory Working Group. 2000. *Scenarios for a Clean Energy Future*. ORNL/CON-476, LBNL-44029, and NREL-TP-620-29379. Oak Ridge, Tenn.: Oak Ridge National Laboratory, Berkeley, Calif.: Lawrence Berkeley National Laboratory, and Golden, Colo.: National Renewable Energy Laboratory.

Kushler, Martin, Dan York, and Patti Witte. 2003. *Responding to the Natural Gas Crisis: America's Best Natural Gas Energy Efficiency Programs.* Washington, D.C.: American Council for an Energy-Efficient Economy.

Miller, Peter, Joe Eto, and Howard Geller. 1989. *The Potential for Electricity Conservation in New York State.* Energy Authority Report 89-12. Prepared by the American Council for an Energy-Efficient Economy. Albany, N.Y.: New York State Energy Research and Development Authority.

Nadel, Steven, Joe Eto, Mark Kelley, and Jennifer Jordan. 1994. *Gas DSM and Fuel-Switching: Opportunities and Experiences.* Energy Authority Report 94-10. Prepared by the

American Council for an Energy-Efficient Economy. Albany, N.Y.: New York State Energy Research and Development Authority.

Nadel, Steven and Howard Geller. 1995. *Utility DSM: What Have We Learned, Where Are We Going?* Washington, D.C.: American Council for an Energy-Efficient Economy.

Nadel, Steven and Harvey Tress. 1990. *The Achievable Conservation Potential in New York State from Utility Demand-Side Management Programs.* Energy Authority Report 90-18. Prepared by the American Council for an Energy-Efficient Economy. Albany, N.Y.: New York State Energy Research and Development Authority.

Optimal Energy, et al. 2003a. *Energy-Efficiency and Renewable Supply Potential in New York State and Five Load Zones.* Draft. Bristol, Vt.: Optimal Energy, Inc.

———. 2003b. *Vermont Department of Public Service Electric and Economic Impacts of Maximum Achievable Statewide Efficiency Savings, 2003–2012: Results and Analysis Summary.* Public Review Draft of January 31. Bristol, Vt.: Optimal Energy, Inc.

Puget Sound Energy. 2003. "Estimates of Potential Electricity and Natural Gas Savings, 2004-2013." Presentation to Conservation Resource Advisory Group and Least Cost Plan Advisory Group Meeting, July 16, 2003. WA: Puget Sound Energy.

[RLW] Analytics, Inc. and Shel Feldman Management Consulting. 2001. *The Remaining Electric Energy Efficiency Opportunities in Massachusetts.* Middletown, Conn.: RLW Analytics, Inc. and Middleton, Wisc.: Shel Feldman Management Consulting.

Rufo, Michael and Fred Coito. 2002. *California's Secret Energy Surplus – The Potential for Energy Efficiency.* Hewlett Foundation Energy Series. San Francisco, CA: The Energy Foundation.

[SWEEP] Southwest Energy Efficiency Project. 2002. *The New Mother Lode: The Potential for More Efficient Electricity Use in the Southwest.* http://www.swenergy.org/nml/index.html. Bolder, Colo: Southwest Energy Efficiency Project.

Xcel Energy. 2003. *Biennial Plan for 2003 and 2004 Minnesota Natural Gas and Electric Conservation Improvement Program*. Minneapolis, Minn.: Xcel Energy.

York, Dan and Marty Kushler. 2002. *State Scorecard on Utility and Public Benefits Energy Efficiency Programs: An Update.* Washington, D.C.: American Council for an Energy-Efficient Economy.