

## **The Technical, Economic and Achievable Potential for Energy-Efficiency in the U.S. – 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 U.S. These studies cover many regions (e.g. California, Massachusetts, New York, Oregon, Utah, Vermont, Washington, the Southwest and the U.S. as a whole), sectors (residential, commercial, and sometimes industrial), energy types (electricity and/or natural gas) and time frames (e.g., 5, 10 and 20 years). This paper summarizes the results of these different studies and then compares and contrasts them to tease out overarching findings. The 11 recent studies examined in this paper show that a very substantial technical, economic and achievable energy efficiency potential remains available in the U.S. 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. The paper concludes with several recommendations for future energy efficiency potential work.

### **Introduction**

In the 1980s and early 1990s a variety of studies were conducted by states and utilities 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 residential, 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, Eto, Kelley and Jordan 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 examined a total of 11 different studies including ones examining the U.S. as a whole (Interlaboratory Working Group 2000) and studies on California (Xenergy 2002 and 2003), Massachusetts (RLW Analytics and Shel Feldman Management Consulting 2001), New York (Optimal Energy et al. 2003), Oregon (Ecotope 2003a and 2003b), Southwestern states (SWEEP 2002), Utah (GDS 2004), Vermont (Optimal Energy 2003), and portions of Washington state (Puget Power 2003). In addition, studies are now underway in Connecticut and Georgia but were not ready in time for inclusion in this paper.

## **Analysis of Recent Studies**

### **Overall Savings**

Savings potential across the 11 studies range from a 5% achievable savings potential for natural gas throughout the U.S. over a ten-year period (Interlaboratory Working Group 2000) to a technical savings potential of 40% or more in studies on Oregon and Washington State. 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 include 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 included and only include the longest time period and the more aggressive scenarios. Other estimates are discussed in subsequent sections of this paper.

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

Region	Year	Fuel	# Years	Potential (%)		
				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%

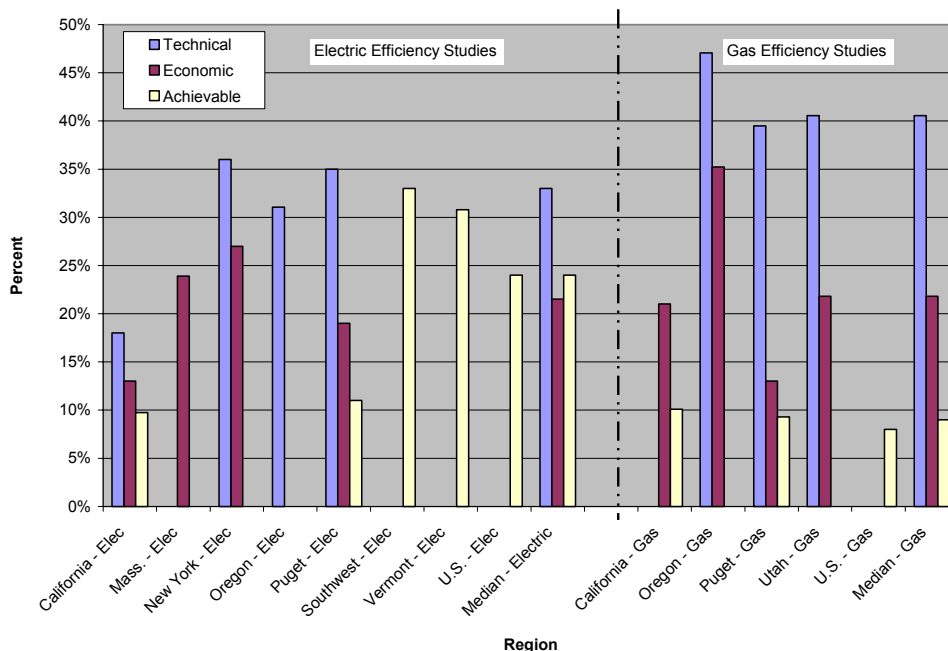
Note: This table only includes the longest time periods and more aggressive scenarios covered in each study.

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 will 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%. Across the different studies, the technical potential for electricity savings ranged from 18-36% with a median of 33%. Most of the estimates were in the 31-36% range, except for the California study which only looked at technologies ready for wide-spread promotion today and generally constrained the technical potential to equipment that needs to be replaced over the next ten years. For natural gas, technical savings potential ranged 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 life-cycle 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 ranged from 13-27% with a median of 21.5%. Again, the California study provides the lowest estimate. For natural gas, the economic potential ranged from 13-35% with a median of 20%. Most of the estimates ranged 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 raised 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 ranged from 10-33%, including two studies estimating 10-11%, two estimating and 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 Power which appears to include high measure costs and eliminated many measures for poor economics [I have messages into the authors to check this further]. The two high estimates (for Vermont and the Southwest) are for very aggressive program and policy efforts. For example, the Vermont study labels its estimate “maximum achievable” and states 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.”

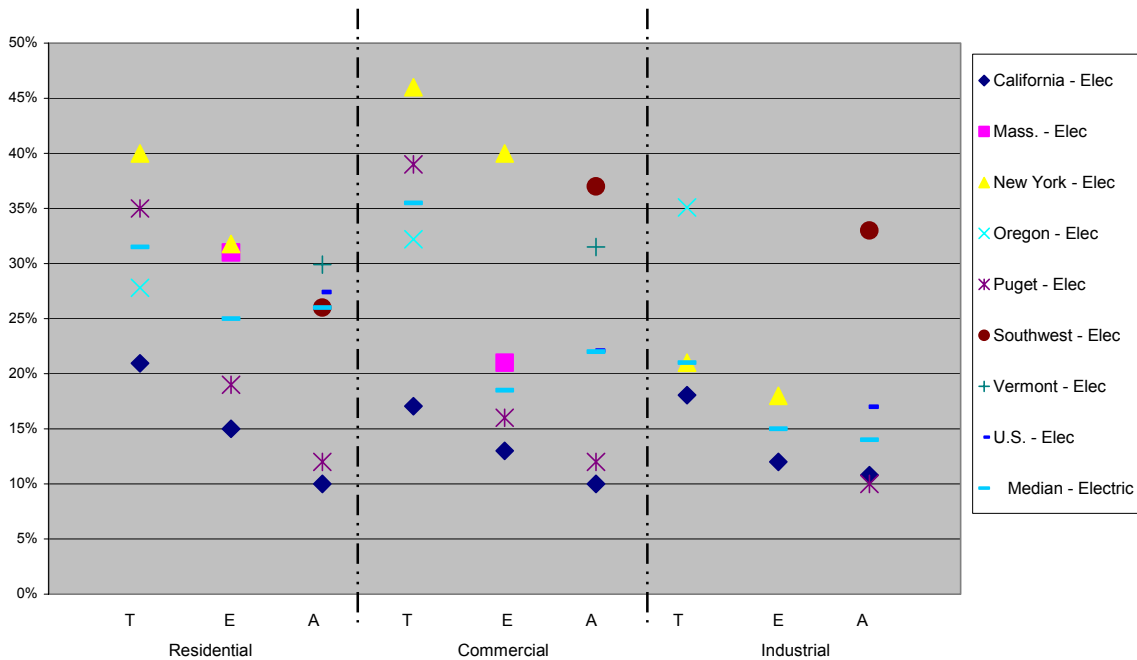
For natural gas, the achievable potential estimates ranged from 8-10% with a median of 10%. These include the California and Puget Power studies which previously were cited as having relatively low achievable potential estimates for electricity.

### Differences by Sector

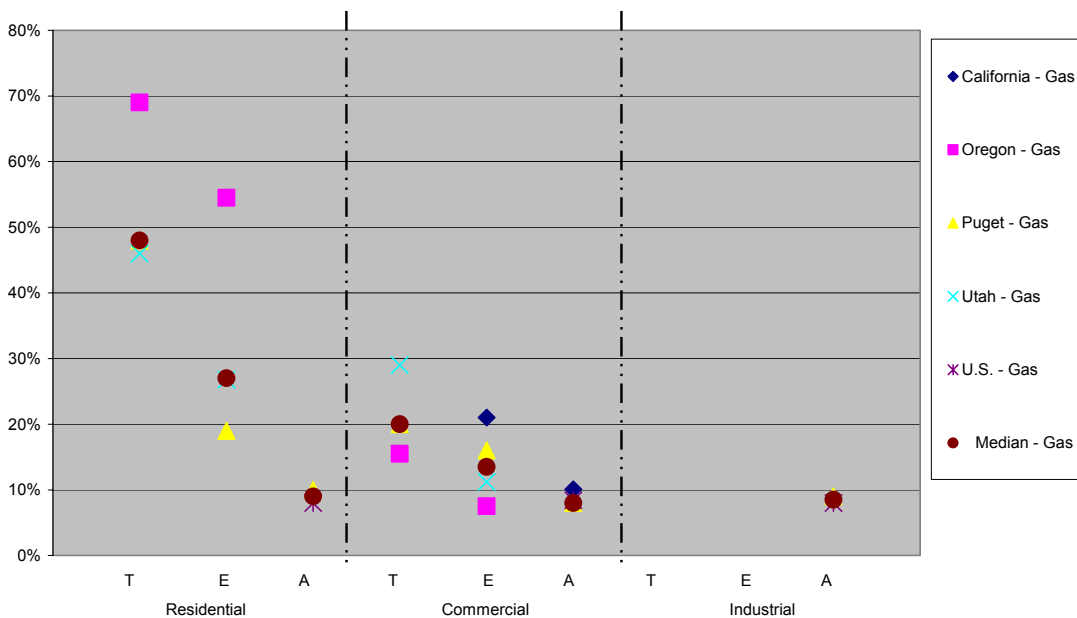
Figures 2 and 3 summarize the savings potentials across the three sectors. Figure 2 covers electricity, Figure 3 natural gas. These figures graph the technical, economic, and achievable potential savings estimates for the residential, commercial and industrial sectors and also display the median for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

For electricity, the median study finds 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 provide achievable potential but not economic potential.

**Figure 2. Summary of Electricity Savings Potential by Sector.**



**Figure 3. Summary of Natural Gas Savings Potential by Sector.**



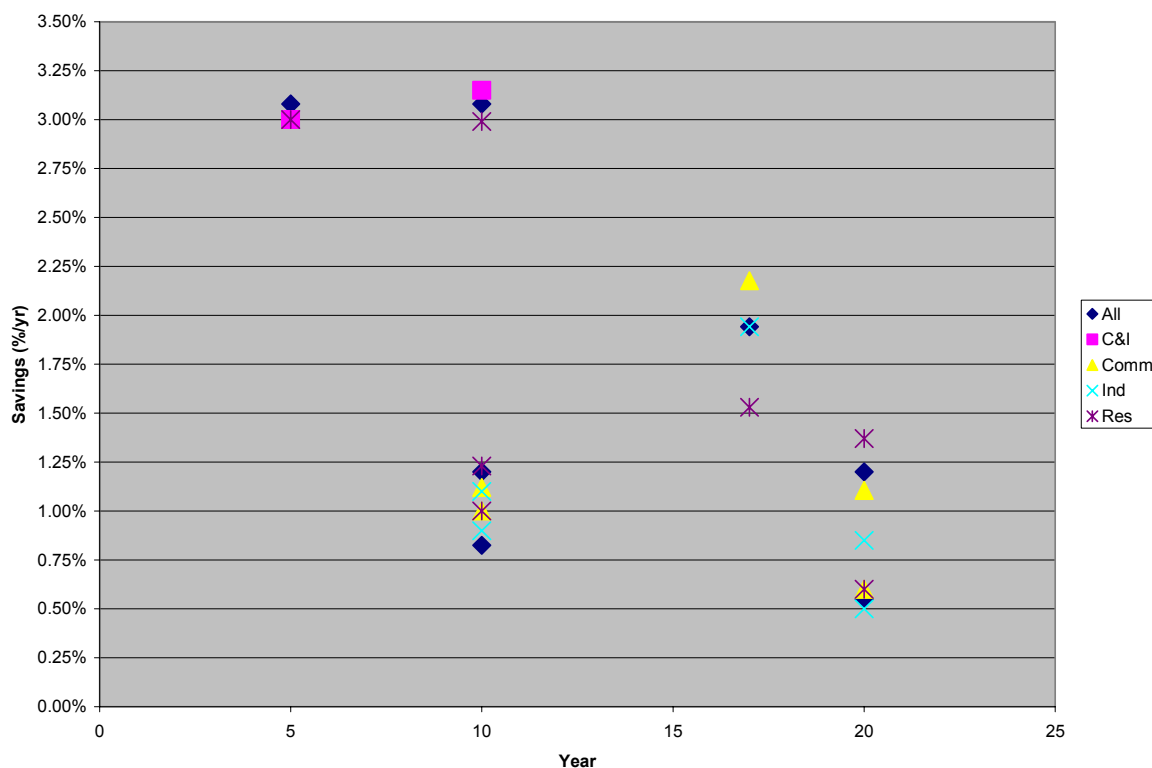
For natural gas, savings potentials appear to be highest in the residential sector and lower in the commercial sector. The median technical potential is 48% in the residential sector and 20% in the commercial sector. For the economic potential the medians are 27% and 14% savings respectively, while for 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 are likely 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 difficulty looking at technologies more than a decade into the future, so this drop-off in the second decade is to be expected.

**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/year estimate for each end-use, and compared these medians to the median savings/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, Shipley, Nadel and Brown 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 between the Studies**

In the sections above, several reasons are discussed for differences between studies. For example, the California electricity saving study shows lower technical and economic potential than many of the other studies because it examined a limited number of measures and limited often limited the technical potential to equipment that would be replaced over the next ten years. Likewise, the Puget study found a low achievable potential because due to relatively high measure costs [confirm]. On the other hand, the Vermont and Southwest studies found very high achievable potential because they assume 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 are noted above to be fairly conservative, and the third of which (the U.S.-wide study) uses 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 between studies can be attributed to several factors including:

- The methodology employed (e.g. limiting technical and economic potential to natural turn-over 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);
- 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 report have 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%/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 0.5-1.0% 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	4760	239,654	2.0%
	2002	[still getting #]	235,249	[to be calculated]
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 U.S. 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 examine 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 replace 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 examine 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.

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