

Electric Utility Demand Side Management:  
Defining and Evaluating Achievable Potential

by  
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May 2008

Masters project submitted in partial fulfillment of the  
requirements for the Master of Environmental Management degree in  
the Nicholas School of the Environment and Earth Sciences of  
Duke University  
2008

## **Abstract**

Projections of demand side management efficiency potential can inform electric utility program design and policy compliance. Beyond technology and cost, “achievable potential” estimates explore factors that facilitate end-use efficiency advances. This study compiles state level ex ante achievable potential estimates, explores estimation methods, and compares ex ante estimates with ex post energy efficiency load reductions. Quantitative analysis indicates that ex ante estimates and ex post reductions are correlated; they do not differ significantly. While ex ante estimates may appropriately estimate ex ante reductions, ex ante estimates are noisy and capture little variation in the ex post efficiency gains. Qualitative review of demand side management program evaluations identifies multiple factors absent from achievable potential estimates. Inclusion of these factors could refine achievable potential estimates. Generally, achievable potential estimates have improved over the past decade but remain hindered by inconsistency and oversimplified assumptions. This study provides a platform for continued clarification of achievable potential definitions and estimation methods. The importance of achievable potential accuracy grows with demand side management’s role in climate change strategy.

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## **Introduction**

Electric utility demand side management (DSM) programs seek to reduce electric loads from the end-user or consumer through energy efficiency (EE) and load-shaping measures. Successful demand side management programs, stimulated by state incentives, requirements, and financial structures, can reduce the amount of electricity a utility must provide, decreasing the need for new generation sources (Williams et al., 2007: 1-2). Reduction in electricity demand generally translates to reduction in greenhouse gas emissions produced by generation. Estimations of DSM load reduction potential inform utility management strategies and climate policy. The accuracy of such estimates can affect plans for future programs, policies, generation sources, etc. (Nadel, 2004).

DSM energy efficiency potential estimates typically involve a three tiered approach: technologically feasible, cost-effective, and achievable potential estimates. First, existing, market-ready technologies that have the ability to reduce electric load are identified. Second, varying cost-effectiveness tests distinguish which of these technically feasible projects are cost-effective. Beyond technology and cost, however, many factors can affect the success of a demand side management program. Regulation, funding levels, education and perceptions, physical climate, and other factors could affect program participation and technology penetration. Achievable potential is the third step in program potential estimation. Achievable potential incorporates factors that influence participation and penetration through a variety of methods. Achievable potential estimation procedures are not well-established but are important for effective DSM implementation decisions.

This study addresses definitions, estimation methods, and factors important in DSM energy efficiency achievable potential. The literature review summarizes relevant terms and current research. Three analysis sections consist of a compilation of state-wide achievable potential estimates, a quantitative ex-post verification of the estimates, and a qualitative investigation of DSM program evaluation results. Each analysis section frames the question and includes data, methods, results, and discussion. The exploration of factors important to achievable DSM projects has significance for a wide range of stakeholders; results can inform decision making by utilities, policy makers, electric consumers, and others with interest in demand side management programs. This analysis provides a platform for continued clarification of achievable potential estimation methods.

## **Literature Review**

### *Terminology and Methodology*

The terms *technologically feasible*, *cost-effective*, and *achievable* have been used in regard to electric utility demand side management projects in the United States for years (Vine et al., 2007). Though terminology varies, definitions from EPA (2007) for technically feasible, cost-effective, and achievable potential summarize the most common use of the terms in potential studies from the past decade. In some cases, the meanings of “achievable potential” and “program potential” can overlap. Many studies report “program potential” as a level of “achievable potential” or refer to levels of program funding as levels of achievable potential. Terms used in this study maintain the meanings identified by the EPA but include only “achievable potential” rather than both “achievable potential” and “program potential.”

“**Technical potential** is the theoretical maximum amount of energy use that could be displaced by efficiency, disregarding all non-engineering constraints such as cost-effectiveness and the willingness of end-users to adopt the efficiency measures. It is often estimated as a ‘snapshot’ in time assuming immediate implementation of all technologically feasible energy saving measures, with additional efficiency opportunities assumed as they arise from activities such as new construction.

“**Economic potential** refers to the subset of the technical potential that is economically cost-effective as compared to conventional supply-side energy resources. Both technical and economic potential are theoretical numbers that assume immediate implementation of efficiency measures, with no regard for the gradual “ramping up” process of real-life programs. In addition, they ignore market barriers to ensuring actual implementation of efficiency. Finally, they only consider the costs of efficiency measures themselves, ignoring any programmatic costs (e.g., marketing, analysis, administration) that would be necessary to capture them.

“**Achievable potential** is the amount of energy use that efficiency can realistically be expected to displace assuming the most aggressive program scenario possible (e.g., providing end-users with payments for the entire incremental cost of more efficiency equipment). This is often referred to as maximum achievable potential. Achievable potential takes into account real-world barriers to convincing end-users to adopt efficiency measures, the non-measure costs of delivering programs (for administration, marketing, tracking systems, monitoring and evaluation, etc.), and the capability of programs and administrators to ramp up program activity over time.

“**Program potential** refers to the efficiency potential possible given specific program funding levels and designs. Often, program potential studies are referred to as ‘achievable’ in contrast to ‘maximum achievable.’ In effect, they estimate the achievable potential from a given set of programs and funding. Program potential studies can consider scenarios ranging from a single program to a full portfolio of programs. A typical potential study may report a range of results based on different program funding levels” (EPA, 2007: 2-4).

Though energy efficiency potential studies generally use similar terminology, procedures for estimation of potential are not the same across the board. When a study begins, a subset of market-ready technologies is selected. Current energy efficiency programs and, therefore, potential studies focus on improvements in energy-efficient lighting, motor and space heating and cooling technology, office product technology,

adoption rates, etc. (Williams et al., 2007).<sup>1</sup> Technological feasibility considers the estimated energy savings for each technology as constrained by applicability and feasibility. Applicability addresses a technology's relevance in a particular situation, and feasibility refers to whether installation is physically practical (Itron, 2006). For example, technical potential can be calculated by adding the adjusted estimated energy savings for each market-ready technology:

“Technical potential =  $\sum_i$  (estimated savings<sub>*i*</sub> × applicability factor<sub>*i*</sub> × feasibility factor<sub>*i*</sub>)” (Itron, 2006: 39). The level of factors included in a technical potential estimate shape the total estimate.

Next, conventional utility analysis of energy efficiency potential (and many other types of projects) relies on cost-effectiveness tests. The total resource cost test, the utility test/revenue requirements test, the ratepayer test/cost comparison test, the participant cost test, and the societal cost test each address the perspective of a category of stakeholders (e.g. EPA, 2007; Minnesota, 2005). The selection of a specific test can generate different costs and benefits, weighing heavily in program selection (Table 1). A societal cost test, for example, addresses externalities and non-energy benefits of a decision.

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<sup>1</sup> The number of technologies varies by study from 12 to 106 per sector.

Table 1: Description of cost tests used in cost-effectiveness potential (Source: Rocky Mountain Institute, 2007).

Name of Test	What it Measures	Costs	Benefits
Participant Cost (PCT)	Are expenditures lowered for program participants?	Cost of technology, after incentives (rebates)	Bill savings
Program Administrator (Utility) Cost (PAC)	Are utility revenue requirements lowered?	Incentive paid to customer; marketing, EM&V, admin costs	Avoided energy and capacity costs
Rate Impact Measure (RIM)	Are utility rates lowered?	Incentive paid to customer; lost revenues; marketing, EM&V, admin costs	Avoided energy and capacity costs
Total Resource Cost (TRC)	Are total customer expenditures lowered?	Cost of technology; marketing, EM&V, admin costs	Avoided energy and capacity costs

Technology and cost modeling outputs vary with inputs, but methods are generally similar and understood well across the electricity industry. Technology and cost results, produced through well-established modeling techniques, have traditionally been reported in energy efficiency potential studies. New York, for example, contracted out multiple technical and economic potential studies in the early 1990s (Nadel, 2004). Beyond technology and cost, achievable potential estimates have traditionally relied on best guess estimates from experts or references to past achievement in DSM programs (Rocky Mountain Institute, 2007). Levels of detail vary greatly among such estimates, and additional refinement is needed.

### *Current Research*

Discussion from the early 1990s regarding the methods behind energy efficiency potential estimates has resurfaced in recent years (Vine et al., 2007). Climate change concerns have heightened general interest in DSM, and funding for programs has

increased over the past decade (Tierney, 2008). Recent academic work on demand side management and end-use energy efficiency addresses the need for additional programs and highlights the factors evident in their success and failure.

Horowitz (2007) explores electric demand changes over time in the U.S., determining that efficiency programs have had a significant effect and spread particularly quickly in residential markets. His results indicate that states committed to energy efficiency (through policy, funding, or specific targets) have reduced their energy intensity (Horowitz, 2007).

Loughran and Kulick (2004) find that although energy efficiency expenditures lower electricity sales, expenditures are not as effective as utilities report. Utility data identify yearly energy savings from efficiency between 1.8 and 2.3% per year, but Loughran and Kulick find savings between 0.6 and 1.2% per year for utilities that consistently report positive DSM spending (2004: 39). Beyond cost, factors that impact technology penetration are emphasized.

Gillingham et al. (2004) provide prescriptive conclusions from retrospective analysis of DSM programs and currently are compiling a more in-depth study. They find that current DSM programs have a modest impact, but future programs have potential for further reductions, depending on their design and cost (Gillingham et al., 2004).

Mosenthal et al. (2000) use a modified Delphi approach to predict market transformation effects from utility programs. Experts estimate market effects independently, with teams and public comment, and again in teams. Study results indicate that this process is viable (Mosenthal et al., 2000). Because achievable potential estimates vary greatly, a similar expert input process could be informative.

While demand side management is prominent in the literature, the majority of research specific to achievable potential estimates has taken place in professional rather than academic environments. The non-profit American Council for an Energy-Efficient Economy (ACEEE) provides background pieces on the issues of estimation (Nadel, 1992; Nadel and Geller, 1996) and a well-cited compilation of potential estimates (Nadel et al., 2004). *The Technical, Economic and Achievable Potential for Energy-Efficiency in the U.S. – A Meta-Analysis of Recent Studies* reviews eleven energy efficiency potential analysis studies, five of which indicate achievable potential (Nadel et al., 2004). This compilation of estimates indicates a U.S. average achievable reduction potential of 1% annually.

Difficulty in estimating achievable potential on a case by case basis has led others to reference this 1% per year estimate (Rocky Mountain Institute, 2007). Given historical efficiency achievements, 1% may be low. Meyers et al. (1999) indicate that before funding for DSM programs was reduced in the late 1990s, energy efficiency savings peaked at 2.0% per year (EIA, 1996 in Myers et al, 1999). Estimates ranging from 1% to 2% per year are in line with other studies (Nadel, 1996; Loughran and Kulick, 2004) but merit investigation.

The need for consistency in energy efficiency potential estimates has been recognized recently. In December 2007, the EPA released the *Guide for Conducting Energy Efficiency Potential Studies*. The guide is a supplement to National Action Plan for Energy Efficiency and notes the need for correct potential studies as energy efficiency programs expand. Though it focuses on “understanding the potential for cost-effective energy efficiency” rather than achievability, it highlights important factors in potential

estimation (EPA, 2007: 1-1). The authors, experienced consultants from Optimal Energy, introduce a useful overview of the main steps for estimation and address timely issues from other reports. Likewise, KEMA, an energy consulting firm, provides specific steps for estimation in its 2006 Colorado report.

### *Current Policy*

Utility choices to implement varying levels of DSM programs are influenced by current or pending policy requirements. Motivation for program implementation differs widely and may significantly affect program outcomes. Vine et al. (2006) stipulate that the involvement of regulatory bodies is essential for continued energy efficiency investments. Statewide potential studies are often commissioned to inform this type of policy decisions. Many states have recognized the role of energy efficiency in meeting growing electricity demand and potential climate policy requirements (Prindle et al., 2006).

Indicating policy level dedication to efficiency, states have signed onto the National Action Plan for Energy Efficiency or mandated energy efficiency resource standards (Table 2). An energy efficiency resource standard (EERS) “is a market-based mechanism to encourage more efficient generation, transmission, and use of electricity and natural gas” (Pew, 2008). EERSs often involve utility targets and always include end-use efficiency improvement (Pew, 2008). Likewise, some states include energy efficiency as a viable contribution to Renewable Portfolio standard requirements (i.e. Pennsylvania, North Carolina, and Nevada) (Pew, 2008).

Table 2: State commitments to the National Action Plan for Energy Efficiency or an Energy Efficiency Resource Standard.

State	National Action Plan for Energy Efficiency (Tierney, 2008)	Energy Efficiency Resource Standard (Pew, 2008)
California	x	x
Colorado		x
Connecticut	x	x
DC	x	
Hawaii		x
Illinois		x
Iowa	x	
Maine	x	
Minnesota	x	x
Nevada		x
New Jersey	x	pending
New Mexico		x
New York	x	pending
North Carolina	x	x
Pennsylvania		x
Texas	x	x
Vermont		x
Virginia		x
Washington	x	x

State EERS requirements vary. Minnesota recently passed a requirement (SF 145) of 1.5% savings per year for both electricity and natural gas. A minimum of 1% per year has to come from “utility energy efficiency programs” (Kushler 2007: 12). Illinois’s EERS (SB 1184) for electricity and natural gas starts with a requirement of 0.2% per year and increases to 2% per year by 2015 (Kushler 2007: 13). In Washington state, an initiative that requires “utilities to implement all cost-effective energy efficiency measures” has been approved (Pew, 2008). Washington’s most recent plan indicates that by 2010 utilities should identify their future energy efficiency potential (Pew, 2008). These policies indicate an increased interest in demand side management energy efficiency programs.

Likewise, current EU standards cite a goal of 1% reduction in electricity demand through efficiency yearly. An EU directive requires members to plan for a 1% average annual energy savings from energy efficiency measures by final customers (end-users) over the nine years from 2008 to 2017 (Europa, 2008).

## **Efficiency Potential Study Analysis**

### *Methods and Data*

An end-use efficiency potential study is often the first step taken by a state or utility considering an efficiency policy or program. Since 1998, more than twenty states have commissioned energy efficiency potential studies referencing some form of achievable potential.

This analysis includes thirty-six publicly available, U.S. based studies that specifically reference achievable potential. Studies were identified through comprehensive searches of energy consulting firm publications and references in other energy efficiency potential work. As much demand side management data remain confidential property of electric utilities, their consultants, and regulatory agencies, some studies may be missing from the analysis. The majority of estimation work in the available studies was completed by consulting firms such as ICF, KEMA, Optimal Energy, and Vermont Energy Investment Corporation.

Studies typically report efficiency potential results for electricity and natural gas use in residential, commercial, and industrial sectors. The potential changes from DSM implementation are measured in comparison to typical sales and summer peak demand for both load reduction and load shaping. To narrow the scope of this analysis, a subset

of these results is addressed. Electricity estimates, rather than natural gas estimates, are more prominent in the literature. Efficiency as a percentage of typical sales, rather than summer peak demand, offers a more general look at yearly potential. Load reduction through efficiency, rather than load shaping, makes up the large part of demand side management program implementation (over 90% in 2006) (EIA, 2006). Therefore, this analysis focuses solely on aggregate electricity load reductions as a percentage of sales. Residential, commercial, and industrial sector results are reported where available, but all comparisons are made at the aggregate level.

This analysis compiles and reviews definitions of and estimates for potential levels from each study. Where studies report achievable potential estimates differently, results have been adjusted for comparison. For example, a typical achievable potential estimate projects efficiency savings out to a particular year and reports savings as a percentage of projected demand in that year. A projection for Colorado demonstrates cumulative savings from 2006 to 2015 (Figure 1). In order to compare studies that incorporate different time periods, the end year potential is distributed across the estimation time period. For example, if efficiency savings potential in 2015 is 9% of 2015 projected demand, 9% is divided by the number of years between 2006 and 2015. This calculation ( $9\%/9$ ) yields a 1% achievable potential per year. The 1% value refers to the percent of the end year projected electric load that could be met with DSM EE measures. Nadel et al. (2004) use a similar calculation in their study compilation analysis. This assumption is appropriate if demand for electricity grows arithmetically but may hinder results if growth of electricity demand depends on use in the previous year. The

calculation is necessary, however, to normalize study estimates for comparison across different time periods.

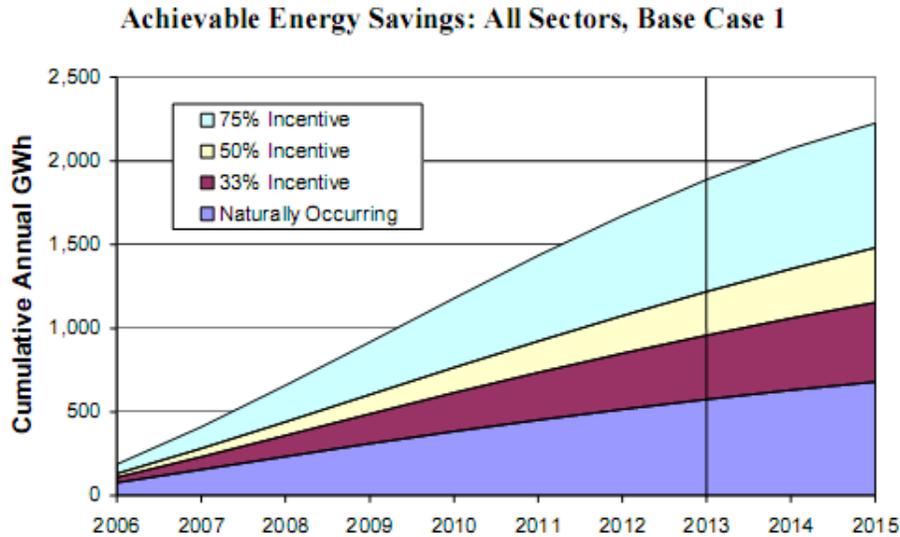


Figure 1: Achievable potential savings in Colorado from 2006 to 2015 (Source: KEMA, 2006: 4-8)

The Colorado estimate also includes multiple achievable potential scenarios. Each segment of the chart indicates a hypothetical level of policy and financial incentives for demand side management programs (Figure 1). Where studies include multiple achievable potential scenarios, the most aggressive achievable potential estimate is selected for comparison. Program funding levels for maximum achievable potential estimates vary by study. Also, a handful of studies report estimates in megawatts rather than percentages. Comparison of megawatt values for efficiency and total sales normalizes these estimates.

## *Results and Discussion*

Building on study compilations by Plunkett (2003), Nadel et al. (2004), and the EPA (2007), Table 3 summarizes recent studies that include achievable potential estimates. Categories and data are modified from an EPA table in the *Guide for Conducting Energy Efficiency Potential Studies* (2007:2-6 to 2-8). All data have been verified with source studies. “Type of savings potential” corresponds to the achievable potential estimation process in a study, not the particular terminology used in a study. “Technical,” “economic,” and “achievable” refer to the EPA definitions of these terms. Levels of “achievable” refer to study specific scenarios, and “achievable before cost” refers to an achievable potential estimate based directly on technical potential rather than cost-effective potential. “Max. achievable” or maximum achievable potential refers to the most aggressive scenario in a study.

Table 3: Ex-ante state-wide studies of achievable electric load reduction potential (Modified from EPA, 2007).

State	Study Author	Year	Years to Achieve Potential	Type of Savings Potential	Estimated Efficiency Savings as % of End Year Projected Sales				Achievable Potential per Year
					Res.	Comm.	Indus.	Total	
Arizona	SWEEP	2003	17	Max. achievable				33.9%	<b>1.99%</b>
Big Rivers (KY)	GDS	2005	10	Economic	16%	10%	9%	12%	<b>1.20%</b>
California	Itron, Xenergy	2004	13	Market average	13.1%	6.4%	4%	25.1%	<b>2.01%</b>
California	LBNL, Quantum, KEMA	2005	12	Max. achievable			5% - 8%		<b>0.67%</b>
California	Xenergy	2002	10	Technical	21%	17%	13%	19%	<b>1.00%</b>
				Economic	15%	13%	12%	14%	
				Min. achievable	10%	13%	11%	10%	
				Max. achievable	8%	7%	4%	6%	
Colorado	KEMA, Quantum	2006	7	Technical				21%	<b>2.29%</b>
Colorado	SWEEP	2003	17	Economic				16%	
Colorado	SWEEP	2003	17	Max. achievable				31.2%	<b>1.84%</b>
Connecticut	GDS, Quantum	2004	9	Technical	24%	25%	20%	24%	<b>1.44%</b>
				Max. achievable	13%	14%	13%	13%	
Florida	ACEEE	2008	15					20%	<b>1.33%</b>
Georgia	ICF	2005	5	Technical	33%	33%	17%	29%	<b>1.74%</b>
				Economic	21%	22%	15%	20%	
				Min. achievable	1.5%	3.3%	2.2%	2.3%	
				Mod. achievable	5.3%	7.5%	5.2%	to	
				Max. achievable	9.4%	9.6%	6.6%	8.7%	
Illinois	ACEEE	1998	20	Achievable				4.3%	<b>0.22%</b>
Iowa	ORNL	2001	15	Max. achievable	5.3%	5.1%	6%	5.4%	<b>0.36%</b>
Maine	Optimal	2003	10	Economic	7%	17%	17%	14%	<b>1.40%</b>
Massachusetts	RLW Analytic, SFMC	2007	5	Economic	31%	21%		24%	<b>1.00%</b>
				Achievable	5%	-		5%	
Massachusetts	RLW Analytics, SFMC	2001	5	Economic	25%	16%	16%	19%	<b>3.80%</b>
Michigan	ACEEE, Optimal, VEIC	2003	10	Achiev. bf cost	10%	18.7%	6%	11.6%	<b>1.16%</b>
Midwest	ACEEE	2003	20	Max. achievable				11%	<b>0.55%</b>
Midwest (IL, MN, WI, IN, KY, MI, MO, OH, IA)	Xcel	2006	20	Technical				20%	<b>0.70%</b>
				Achievable				30%	
Minnesota	Strom	2005	20	Achievable by cost				8 - 14%	
Minnesota	Strom	2005	20					24%	<b>1.20%</b>
New England	Optimal	2005	7	Offset load growth				48% of potential	

State (ctd)	Study Author (ctd)	Year (ctd)	Years to Achieve Potential (ctd)	Type of Savings Potential (ctd)	Estimated Efficiency Savings as % of End Year Projected Sales (ctd)				Achievable Potential per Year (ctd)
					Res.	Comm.	Indus.	Total	
New Jersey	KEMA	2004	16	Technical Economic				23% 17%	<b>1.06%</b>
New York	Optimal, ACEEE, VEIC, Donovan	2003	99	Technical Max. achievable	37% 26%	41% 38%	22% 16%	37% 30%	<b>3.33%</b>
New Mexico	ltron	2006	10	Max. achievable				8%	<b>0.80%</b>
New Mexico	SWEEP	2003	17	Max. achievable				35.8%	<b>2.11%</b>
Nevada	SWEEP	2003	17	Max. achievable				31.1%	<b>1.83%</b>
North Carolina	Duke Energy	2007	5	Technical Economic Achievable				31% 19% 1.6%	<b>0.32%</b>
North Carolina	GDS	2006	11	Technical Achiev. bf cost Economic achiev.	40% 20% 17%	32% 22% 12%	24% 18% 12%	33% 20% 14%	<b>1.27%</b>
Northeast (NY, NJ, PA)	ACEEE	1997	14	Max. achievable	35%	35%	41%	37%	<b>2.64%</b>
Oregon	Ecotope, ACEEE, Tellus	2003	10	Technical	27.8%	32.2%	35.1%	31.7%	<b>3.17%</b>
Puget (WA)	Optimal, ACEEE	2003	20	Achiev. bf cost Economic achiev.	17% 7%	7% 6%	0% 0%	11- 12% 6%	<b>0.55%</b>
Puget (WA)	Puget Sound Energy	2003	20	Technical Economic	17% 7%	7% 6%	0% 0%	12% 6%	<b>0.30%</b>
Southwest (AZ,CO,NV, NM, UT, WY)	SWEEP, ACEEE	2002	8	Max. achievable	14%	20%	19%	18%	<b>2.25%</b>
Texas	OEI	2007	15	Max. achievable				20%	<b>1.33%</b>
Texas	ACEEE	2006	17					11%	<b>0.65%</b>
Utah	SWEEP	2001	6	Max. achievable				9%	<b>1.50%</b>
Utah	SWEEP	2003	17	Max. achievable				31.2%	<b>1.84%</b>
Vermont	Optimal Energy/ VEIC	2003	10	Achiev. bf cost	30%	32%	32%	31%	<b>3.10%</b>
Vermont	GDS	2006	6	Technical Achiev. bf cost Economic achiev.	40% 26% 21%	40% 24% 21%	21% 15% 15%	35% 22% 19%	<b>3.17%</b>
Wisconsin	Energy Center	2000	15		4.9%	4.8%		9.2%	<b>0.61%</b>
Wyoming	SWEEP	2003	17	Max. achievable				35.5%	<b>2.09%</b>
U.S.	ACEEE	2004		Median achievable				24.0%	<b>1.20%</b>
U.S.	DOE	2000	13	Achievable	9%	8%	11%	10%	<b>0.77%</b>

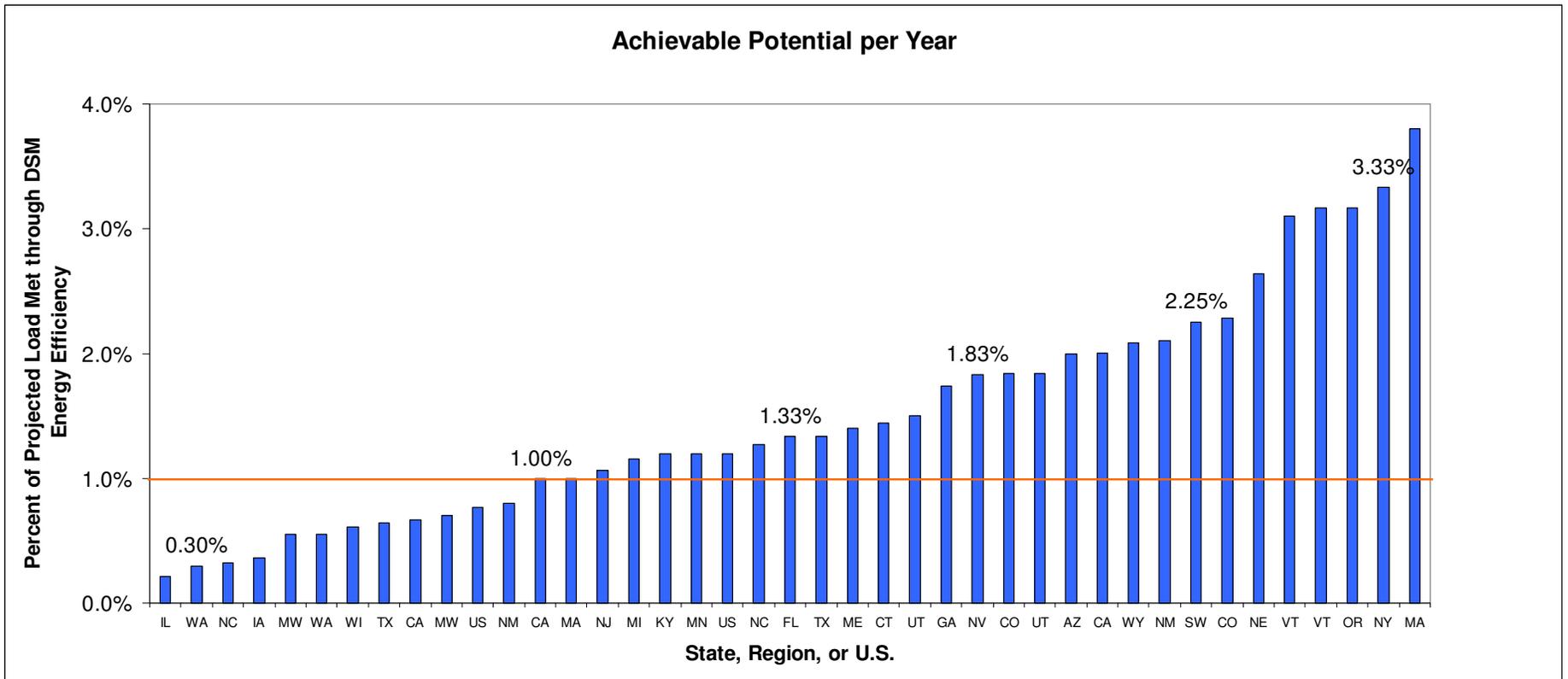


Figure 2: Aggregate achievable potential per year estimates (“Total” column from Table 3).

Achievable potential estimates totaled across sectors fall between 0.22% and 3.80% per year. The bar across Figure 2 denotes the ACEEE's (2004) 1% per year achievable potential estimate for reference. Many estimates lie above this national benchmark.

Estimates vary greatly across sectors and states. Residential and commercial sectors are often cited to have high energy efficiency potential: "On a national basis, residential and commercial sectors display greater total achievable energy savings than industrial" (Nadel, 2004:1-3 in Williams et al., 2007). This result is generally but not systematically true in the state-wide studies reviewed. Biases could be introduced by the cost-effectiveness tests used and the omitted natural gas estimates.

Larger scale studies including a region or the entire United States incorporate more variables than the state-wide studies. The Midwest study, for example, deals with a diversity of electricity rates by dividing the rates into cost categories and estimating twenty year achievable potential percentages for each category (Summit Blue, 2006). ACEEE's nationwide achievable potential estimate, 24%, is the median value for achievable potential from the analyses reviewed in the ACEEE study. This value could be changed, likely lowered, solely by incorporating additional studies. Scaling achievable potential studies up may decrease the reliability of estimates.

Across studies, the primary similarity in the achievable potential estimation process is a focus on levels of program funding and policy scenarios. Both funding and policy are identified as "market barriers" to adoption of technologies. Though some studies reference only one achievable potential estimate, most studies calculate estimates for two or more sample program funding levels. Low and high funding scenarios are

created and applied to the DSM program. The inclusion of detail in such scenarios, however, varies widely among the studies.

Traditionally, achievable potential estimates have relied on the knowledge of experts as well as actual reductions from historic DSM programs (Rocky Mountain Institute, 2007). A Maine study, for example, estimates achievable potential based on the best experience of the authors (Optimal/VEIC, 2002). Optimal Energy and Vermont Energy Investment Corporation perform a detailed analysis of achievability beyond cost-effectiveness for three different types of programs in Maine based on expertise garnered from similar work in Vermont (2002). Rocky Mountain Institute's work for California's Silicon Valley Power (2007) provides prescriptive conclusions about achievable potential, indicating that the utility should consider:

- “1. Baseline: historical savings, based on [EIA form] 1037 reported savings
2. Utility estimates achievable annual penetration, by cost-effective measure, accounting for :
  - Load forecast (*EE easier to achieve in new construction*)
  - Customer mix (*large commercial EE easiest to achieve*)
  - Economies of scale (*larger utilities can achieve more*)
  - % of revenues spent on EE (*more \$ = more savings*)
3. Ability to ramp up this potential based on budget increases.”

Optimal and VEIC address specific technologies while Rocky Mountain Institute focuses on historical savings and utility judgment.

Recent studies of Connecticut, North Carolina, and Vermont deviate from the norm; they estimate cost-effectiveness after rather than before achievable potential (GDS Associates and Quantum, 2003, 2004, 2006). The Connecticut study first estimates technical feasibility and then estimates achievable market penetration of technologies at any cost. A final estimate constrains achievable potential given cost-effectiveness levels determined by historical funding. This reverse estimation method considers technology

availability and market conditions before cost-effectiveness, framing cost-effectiveness as a flexible decision rather than a given input. This type of analysis falls in line with an argument made by Newell (2007): within the definition of cost-effectiveness, assumptions are already made about what programs or energy efficiency technologies are achievable.

Underlying complications in addressing achievable potential are not necessarily addressed in the Maine, Silicon Valley Power, or Connecticut studies. These studies make the assumption that if program funding levels are higher, more efficiency measures will be implemented. Though this trend has often proven true ([www.calmac.org](http://www.calmac.org), 2-25-2008), consumer behavior and adoption of technologies can be complicated. In a Vermont study, consultants note that, “market-driven penetrations are much more variable, depending on the unique barriers to adoption, technology maturity, non-energy benefits, market structure, available recent market [assessments], and past experience” (Optimal, 2003: 35). To address this complexity, energy consulting firms have developed their own estimation methods for energy efficiency potential. KEMA (formerly Xenergy) created the DSM ASSYST model, Itron the Asset model, ICF the Energy Efficiency Potential Model (EPPM), and Quantech the Energy ForecastPro model.

In a 2006 California Energy Efficiency Study, KEMA and Itron’s use of models adds detail to achievable potential estimates. Focusing on industrial potential, they include “estimates of [customer] awareness and willingness that change over time” (Itron et al., 2006: 3-5). KEMA’s DSM ASSYST model “uses S-shaped implementation curves that relate customer benefit-cost ratios to penetration rates of energy efficiency measures” (Itron et al., 2006: 3-7). This Excel-based model “integrates technology-specific

engineering and customer behavior data with utility market saturation data, load shapes, rate projections, and marginal costs into an easily updated data management system” (KEMA, 2006). Likewise, Itron’s Asset model “uses a payback-based logit model to characterize customer adoption of energy efficiency measures” (Itron et al., 2006:3-7). Efficiency measure paybacks are included as a proxy to calculate the probability a customer adopts a technology, and such estimates are combined with non-economic measures involved in technology adoption and past utility program accomplishments. Itron’s model forecasts for particular “decision states:” new construction, replacement on burnout, equipment conversion, and device retrofit (Itron et al., 2006: 3-8). The California report notes that “KEMA’s method of estimating measure adoption takes into account market barriers and reflects actual consumer- and business-implicit discount rates” (Itron et al., 2006: 3-7).

The accuracy of estimates from the 2006 California study, however, is yet to be proven. A white paper on California energy efficiency codes and standards indicates that the KEMA estimates of achievable potential “do not address savings contributions from legal standards” such as appliance standards and building codes (Mahone et al., 2005: 7). Updated standards will likely affect the outcome of DSM programs. Plunkett (2007) addresses this issue in a New England study by assuming overlap of codes and standards with savings from potential studies before reporting potential estimates.

The 2005 Georgia potential assessment by ICF Consulting is particularly thorough. The ICF Energy Efficiency Potential Model is used for the technical, cost-effective, and achievable potential estimates. Similar to KEMA’s ASSYST model, this model estimates achievable potential by projecting “the market penetration of energy

efficiency measures along the characteristic S-shaped adoption curve” (ICF, 2005: 2-10). The market adoption curves are calibrated for the Georgia scenario based on historical efficiency programs in order to model naturally occurring, minimally aggressive, moderately aggressive, and very aggressive scenarios. Similar to the Asset model, the EEPM “tracks the turnover of energy consuming equipment” for replacement at end of life, replace-on-fail, measures that do not replace any equipment, and highly cost-effective measures that replace existing equipment (ICF, 2005: 2-11). The ICF model (2005) also estimates incremental costs, incentive costs, administrative, marketing and outreach costs for each level of achievable potential.

The achievable potential estimates from these more intricate models generally fall in line with more straightforward estimates. However, the models provide more detail about different achievable potential scenarios and the factors important in program implementation (Figure 3). The detailed models each consider the reasons customers adopt technologies, funding scenarios, and type of efficiency replacement. These factors could be important to accuracy or retrospective analysis. On the other hand, detailed models also rely on input from experts to subjectively qualify some aspects of customer awareness and willingness.

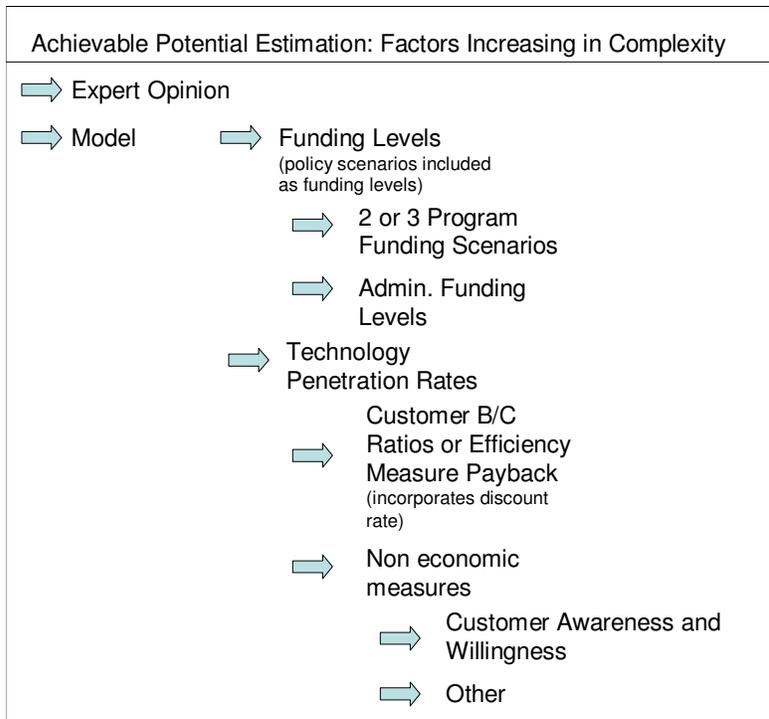


Figure 3: Organization of achievable potential estimation process in increasing complexity.

## Ex Ante vs. Ex Post Evaluation

### *Methods and Data*

Quantitative comparisons of achievable potential estimates and actual reductions in end-use efficiency can inform the achievable potential estimation process. *Ex ante* refers to the achievable potential estimates, or the energy efficiency potential projected from a project. The statewide studies generally address ex ante potential for end-use reduction if DSM programs were expanded or additional programs were implemented. *Ex post* estimates identify actual reductions in electricity end-use achieved through a DSM program. Identifying reductions in end-use can be complicated as a variety of factors affect changes in electricity use (Gillingham et al., 2004). Comparing baseline

and actual use values to determine efficiency gains can be subjective, but relatively standardized procedures exist (EPA, 2007).

The importance of the ex ante - ex post comparison has been recognized at the state and national level. Recent program evaluation requirements in California require that evaluation reports include ex ante and ex post estimates (TecMarket Works, 2006). The EPA (1993) indicates that the “true-up” of ex ante projections of savings with ex post measurements requires consideration of many factors but will “reassure regulators, load forecasters and procurement planners that the savings are real” (4.5:41).

Historical efficiency rates have been used to project achievable potential, but actual program level ex ante - ex post comparisons are not available in DSM and EE literature. The American Council for an Energy Efficiency Economy, for example, has completed separate ex ante and ex post analyses. Nadel et al.’s (2004) compilation of analyses projects a U.S. ex ante achievable potential estimate of 1.0% annually. Using a combination of data from EIA and other sources, York and Kushler (2003) compile ex post energy savings estimates. They calculate a U.S. ex post achieved efficiency reduction of 1.9% in 2003, almost twice Nadel et al.’s ex ante estimate of 1.0%. This study addresses the variation in these estimates by completing quantitative ex ante – ex post comparison.

Ex post data are compiled from a yearly Energy Information Administration survey of electric utilities (form 816) and manipulated in Microsoft Excel and Stata. Data are included from 2001 to 2006. Data from before 2001 are omitted due to a change in reporting requirements. Total annual DSM energy efficiency reductions across sectors are calculated at the utility level and compiled to the state level. To generate ex post

percentages comparable to ex ante achievable potential estimates, these statewide annual efficiency totals are divided by statewide annual electricity sales.

Calculation of the ex post values requires two assumptions. Utilities report DSM energy efficiency reductions for the residential, commercial, industrial, and transportation sectors. Though transportation is not a separate category in statewide ex ante potential studies, it is included in these ex post DSM values. When an electric utility territory spans multiple states, utility scale efficiency results are assumed to be distributed evenly across the states. Distribution by percentages of sales would be appropriate for future analyses (York and Kushler, 2005).

States and utilities generate ex ante estimates as a prediction of ex post efficiency levels. Therefore, it would be expected that ex ante and ex post estimates are similar. A *t*-test of the means of the ex ante – ex post data can provide information about the similarities or differences between the data sets. Regression analysis explores the ex ante – ex post relationship more thoroughly.

Equation 1 describes the predicted relationship between ex post and ex ante estimates: ex post estimates for a certain state in a certain year ( $P_{it}$ ) should equal ex ante estimates for that state and year ( $A_i * t$ ). Factors that vary by state, such as policy or funding levels, electricity generation mix, and population, may affect the ex ante – ex post relationship. To control for such observable or unobservable variables, a state-specific fixed effects variable is included ( $\delta$ ). The error term is assumed to be identically and independently distributed across all observations, with a mean of zero.

Equation 1:

$$P_{it} = A_i \cdot t + \delta_i + \varepsilon_{it}$$

Where P = ex post reduction from sales,  $i$  = state level observation,  $t$  = year, A = ex ante prediction,  $\delta$  = state specific fixed effects, and  $\varepsilon$  = error.

Because the model is based on a limited amount of data, state-level fixed effects, or dummy variables for 49 states, cannot be included. A differences-in-differences model eliminates the need for the dummy variables by netting out state fixed effects. Equation 2 indicates that a change in a state's ex post efficiency from one year to the another ( $\Delta P_{it}$ ) should equal the ex ante estimate for that state ( $A_i$ ) times the change in time since the ex ante estimate ( $\Delta t$ ). The error term is assumed to be identically and independently distributed across all observations, with a mean of zero.

Equation 2:

$$\Delta P_{it} = \beta \cdot A_i \cdot \Delta t + \Delta \varepsilon_{it}$$

Where  $\Delta P$  = change in ex post reduction from sales,  $i$  = state level observation,  $t$  = year,  $\beta$  = coefficient, A = ex ante prediction,  $\Delta t$  = change in year since ex ante prediction, and  $\Delta \varepsilon$  = change in error.

Assuming Equation 1 is true, or that state fixed effects are the only difference between ex ante and ex post estimates, the coefficient  $\beta$  in Equation 2 should equal one. If something else is causing a discrepancy between ex ante and ex post estimates,  $\beta$  will not equal one. If  $\beta$  does not equal one, ex ante estimates are not accurately predicting the ex post achieved potential.

## *Results and Discussion*

Ex ante – ex post estimates are similar in magnitude (Table 4). The U.S. ex post value steadily increases from 1.84% in 2001 to 2.04% in 2006. Like York and Kushler's (2003) estimate, these ex post values are double Nadel et al.'s (2004) ex ante prediction of 1% per year. At the state level, however, ex post values are not systematically greater than ex ante predictions.

To compare the mean of the ex ante data with the mean of ex post data in each year from 2001 to 2006, *t*-tests were completed. Although output indicates that the mean of the ex post data is greater than the mean of the ex ante data in each year, this result is *not* statistically significant. The difference between the ex ante and ex post means is *not* statistically different from zero.

Because ex ante estimates are reported as a percentage achievable over a specific time horizon, ex ante – ex post comparison on an annual basis may not be entirely accurate. Efficiency efforts could be distributed differently over time, for example, many inexpensive projects could be implemented in the first year of a program. Vermont has a higher ex post efficiency level in 2002 (4.80%) and a lower level in 2006 (1.52%). In this case, the Vermont ex ante achievable potential estimate (~3.4%) may be appropriate. Completion of a *t*-test between the mean of the ex ante estimates and the mean ex post level each year addresses this issue.

Table 4: Comparison of ex ante achievable potential estimates from varying years and ex post achieved efficiency levels from 2006.

<b>State</b>	<b>Ex Ante Estimate</b>	<b>2006 Ex Post (EIA)</b>
U.S.	1.20%	2.04%
U.S.	0.77%	2.04%
Arizona	1.99%	0.54%
California	2.01%	6.46%
California	0.67%	6.46%
California	1.00%	6.46%
Colorado	1.84%	1.75%
Colorado	2.29%	9.02%
Connecticut	1.44%	9.02%
Florida	1.33%	2.90%
Georgia	1.74%	0.20%
Iowa	0.36%	1.28%
Illinois	0.22%	0.40%
Big Rivers (KY)	1.20%	0.22%
Massachusetts	1.00%	3.54%
Massachusetts	3.80%	3.54%
Maine	1.40%	0.00%
Michigan	1.16%	0.72%
Midwest	0.55%	4.24%
Midwest	0.70%	0.01%
Minnesota	1.20%	0.04%
North Carolina	0.32%	0.14%
North Carolina	1.27%	0.14%
Northeast	2.64%	0.01%
New Jersey	1.06%	1.56%
New Mexico	0.80%	0.23%
New Mexico	2.11%	0.23%
New York	3.33%	0.57%
Oregon	3.17%	0.29%
Southwest	2.25%	0.00%
Texas	1.33%	0.07%
Texas	0.65%	1.19%
Utah	1.50%	0.19%
Vermont	3.10%	1.52%
Vermont	3.17%	1.52%
Puget (WA)	0.55%	5.36%
Puget (WA)	0.30%	5.36%
Wisconsin	0.61%	2.37%
Wyoming	2.09%	3.02%

Regression results for the ex ante – ex post differences in differences model (Equation 2) indicate that ex ante estimates do not differ significantly from ex post estimates. Regression output indicates that  $\beta$  does not equal one ( $\beta = -0.7071$ ), but  $\beta$  is not significant ( $p = 0.832$ ). A modified regression allowing the change in year since the ex ante estimate to include negative values yields a similar result ( $\beta = 1.6351$ ,  $p = 0.117$ ). These results suggest that there is no systematic bias in ex ante estimates. Ex ante estimates may reflect ex post reductions but simply be very noisy signals.

Because state level fixed effects are netted out, energy efficiency resource standards do not affect the regression output. There is an interesting correlation, however, between state level energy efficiency resource standards and ex ante estimates. A negative correlation ( $-0.3385$ ,  $p = 0.00$ ) indicates that as ex ante estimates increase, states are less likely to have an energy efficiency resource standard. States that have already implemented an efficiency standard may have captured more efficiency gains in the past than states that have not implemented a standard.

Likewise, high percentages of ex post achieved efficiency may correlate to high spending levels in energy efficiency programs. With stipulations about data accuracy, York and Kushler (2005) indicate that “those states that have shown consistent, high levels of funding support for energy efficiency over time are also those states that are achieving significant energy savings through ratepayer-funded electric energy efficiency programs” (9). Spending levels are an important factor in achievable potential estimates and should be addressed in further work on defining achievable potential.

## **Review of Program Evaluations**

### *Methods and Data*

Demand side management program evaluations are completed after programs are implemented to determine effectiveness and review factors that hindered success. More robust definitions of achievable potential could incorporate these factors, addressing the effect of each factor on end-use efficiency. For example, trends in technology change, weather patterns, or customer attitudes are more clearly evident after a program is complete. Program evaluation results, however, are not systematically included in ex ante evaluations or in policy applications (Horowitz, 2007). Benneer and Coglianese (2006) stress the importance of this process.

California has funded program evaluation of energy efficiency programs heavily (BECC, 2007) and has taken advance action relevant to load reduction evaluation procedures (CPUC, 2006). California energy efficiency evaluation protocols (2006) establish methods for ex post evaluations and indicate that ex post evaluation practices can apply to ex ante evaluations. In *Protocols for Estimating the Load Impacts from Demand Response Programs*, the California Public Utilities Commission (2006) indicates that creation of “both retrospective and forecasting protocols [for DSM are] appropriate” and tries to initiate such discussion (Summit Blue and Quantum, 2006). The National Energy Efficiency Program Evaluation Guide includes estimation methods for ex post program energy savings but does not address ex ante estimates (EPA, 2007).

Currently, incomparability, incompleteness, and lack of rigor are primary problems with energy efficiency evaluation studies (TecMarket Works, 2002-2003). Because baseline and consumption estimation practices vary widely among studies,

comparing quantitative values of factors in ex post evaluations and achievable potential projections is not possible. To circumvent this difficulty, a qualitative analysis form is selected for this section of analysis. Program evaluations are reviewed to identify frequency of barriers to program success.

In a study on market transformation through utility DSM programs, Eto et al. (1996) identify the following barriers to energy efficiency:

“high first costs, information or search costs, performance uncertainties, asymmetric information and opportunism, hassle or transaction costs, hidden costs, access to financing, bounded rationality, organization practices or custom, misplaced or split incentives, product or service unavailability, externalities, nonexternality mispricing, inseparability of product features, and irreversibility” (11-17, details in Appendix).

Current EPA work (2007) identifies similar barriers to efficiency. These fifteen categories are used to systematically identify barriers in DSM program evaluations.

DSM program evaluations associated with electric utilities, addressing technology implementation, and completed after 1998 are included in this analysis. The twenty evaluations were collected from the California Measurement Advisory Council database, the Northwest Energy Efficiency Alliance report compilation, and other sources. A large percentage of California projects may introduce some bias into the selection of market barriers. However, lessons from California programs may translate to other locations.

### *Results and Discussion*

Barriers that appear frequently across program evaluations are negatively affecting many DSM programs (Table 5). Information or search costs, asymmetric information and opportunism, organization practice or custom, and misplaced or split

incentives are the most frequent DSM barriers; they occur in almost half the program evaluations reviewed (Table 6).

Table 5: Frequency of barriers in DSM program evaluations.

	High first costs	Information or search costs	Performance uncertainties	Asymmetric info & opportunism	Hassle or transaction costs	Hidden costs	Access to financing	Bounded rationality	Organization practices or custom	Misplaced or split incentives	Product or service unavailability	Non-externality mispricing	Inseparability of product features	Other / Specific case
2006 PG&E, SCE, SDG&E New and Existing Residential and Commercial AC	x		x	x					x	x	x			
2006 Oregon New Building Efficiency	x	x			x			x		x				
2006 Commercial Windows Initiative		x		x					x					x
2005 SCE, PG&E, SCG, SDG&E Designed for Comfort: Affordable Housing		x					x		x	x				x
2005 NW Microelectronics Market				x				x						x
2005 CA Residential Retrofit Rebate														x
2004 Small Commercial HVAC Pilot				x						x				x
2004 SDGE Residential New Construction High Efficiency Appliance and Lighting	x				x									x
2004 NW Drive Power Initiative												x	x	
2003 SDGE Diverse Market Outreach	x	x		x						x				x
2003 SDG&E Energy Code Training														
2002 PG&E, SCE, SDG&E Building Efficiency: Savings By Design		x					x							x
2002 NYISO PRL Evaluation		x	x			x								x
2002 NW Evaporator Fan VFD Initiative			x	x			x		x					x
2002 CA Energy Star New Homes	x					x	x			x	x			x
1998 SDG&E Residential Market Effects		x	x		x			x	x	x	x			
1998 PG&E Natural Cooling Baseline		x	x	x					x					x
1998 PG&E Comfort Home		x	x	x	x		x		x	x	x			
1997 PG&E Appliance Efficiency														x
<b>TOTAL</b>	<b>5</b>	<b>9</b>	<b>6</b>	<b>8</b>	<b>4</b>	<b>2</b>	<b>5</b>	<b>3</b>	<b>7</b>	<b>8</b>	<b>4</b>	<b>1</b>	<b>1</b>	<b>13</b>

Table 6: Most frequent DSM barriers in ex post program evaluations.

<b>Barrier</b>	<b>Frequency</b>	<b>Already Incorporated in Ex Ante Estimates?</b>	<b>Appropriate Ex Ante Estimate Subsection (Figure 3)</b>
Information or search costs	9	Yes	program administration costs and customer willingness
Asymmetric information and opportunism	8	No	customer awareness and/or customer willingness
Organization practices or custom	7	No	customer awareness and/or customer willingness
Misplaced or split incentives	8	No	efficiency measure payback

Information or search costs (costs of acquiring information) are already included in achievable potential estimates that address program administration costs. The other frequent barriers are not addressed in any ex ante estimates. Asymmetric information and opportunism (sellers knowing more than or misleading buyers), organization practice or custom (organization behavior systems), and misplaced or split incentives (EE benefits not aligned with purchase) could be included in ex ante estimates (Table 6). Customer awareness and willingness factors estimated by KEMA, Itron, and ICF, for example, could incorporate these additional DSM barriers.

Beyond program implementation barriers, there may be other factors missing from both achievable potential estimates and ex post efficiency reduction. Wang (2007) speculates that lack of inclusion of high-tech, transmission, and other sectors biases achievable potential estimates downward. The majority of demand side management programs do not incorporate such sectors in ex ante estimates, program design, or ex post evaluations. ACEEE (2007) notes that “there are also many innovative programs –

programs using new approaches, promoting new technologies, and targeting customer segments that haven't been well-served or even have been entirely missed by past [DSM] programs. Examples include programs targeting industrial processes, agriculture, high tech industries (such as data centers), and the food service industry” (7). Barbour (2008) states that non-traditional energy end-uses are growing quickly and provide new efficiency opportunities.<sup>2</sup> These statements indicate that true levels of achievable energy efficiency potential could be higher than current studies project. Likewise, levels of efficiency potential could vary due to varying motivations for and aggressiveness of demand side management programs.

## **Conclusion**

The review of ex ante estimates, comparison with ex post estimates, and compilation of program barriers summarizes the current state of achievable potential estimates. This analysis is a first step toward creating a standard definition and refining the estimation process for achievable potential.

The state-wide achievable potential estimates confirm that definitions of achievable potential are similar across studies but that estimation methods vary significantly. Compared to past procedures, recent estimation methods have improved. Some energy consulting firms have developed detailed models that account for changes in time and consumer preference. Even these models, however, rely on personal expertise. Overall, estimation methods often make oversimplified assumptions and are not standardized.

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<sup>2</sup> Barbour (2008) lists new and emerging energy efficient technologies: solid state lighting, heat pump water heaters, highly insulating dynamic windows, power supplies, etc.

The data available for demand side management and energy efficiency vary widely. Ex ante – ex post analysis in this study is restricted by the breadth and depth of the data available. More detailed and consistent demand side management and end-use efficiency data is necessary to track program potential and accomplishments. The literature notes a need for consistency across such estimates, but there is no evidence of work toward making such data available.

Using available data, the quantitative comparison of achievable potential estimates and actual end-use reductions indicates that ex ante estimates and ex post estimates are similar overall. The difference in the means of the ex ante-ex post is not significantly different from zero, and ex ante – ex post estimates do not differ significantly. This preliminary result indicates that ex ante estimation procedures may appropriately estimate DSM energy efficiency achievable potential. However, they are clearly quite noisy and capture little variation in the ex post efficiency gains.

Review of demand side management program evaluations indicates, however, that many barriers affecting program success are not incorporated in ex ante estimates. Though the ex ante estimates are not significantly different from the ex post estimates, there is room for improvement. Barriers to DSM success identified frequently in program evaluations, such as information or search costs, asymmetric information and opportunism, organization practice or custom, and misplaced or split incentives, could be incorporated into achievable potential estimates. These factors may help reduce the noise in ex ante predictions and ultimately make these predictions more useful for decision makers.

The importance of appropriate achievable potential estimates grows with their possible role in policies and programs designed to address climate change (Prindle et al., 2006). Estimates currently vary based on previous assumptions about technology and cost, level of detail incorporated, expert speculation, etc. Variation among estimates, however, is only informative if estimates are comparable. A standardized definition and estimation process for achievable potential could improve the accuracy and comparability of achievable potential estimates. A stated process for estimation could allow for variation in assumptions and levels of complexity while ensuring that similar factors are included across definitions. The EPA *Guide for Conducting Energy Efficiency Potential Studies* could incorporate an achievable potential definition and process guidelines.

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## Appendix

From: Eto, J., R. Prael, and J. Schlegel. 1996. A Scoping Study on Energy-Efficiency Market Transformation. California Utility DSM Programs, Berkeley, CA: Lawrence Berkeley National Laboratory, Berkeley, CA.

“**A. Information or search costs**—the costs of identifying energy-efficient products or services or of learning about energy-efficient practices. These can include the value of time spent finding out about or locating an energy-efficient product or service or hiring someone else to do it on the consumer's behalf. Search costs can be thought of as costs of acquiring information.”

“**B. Performance uncertainties**—the difficulties consumers face in evaluating claims about future benefits, which are made for many energy-efficiency investments and activities. This market barrier is closely related to high search costs; acquiring the information needed to evaluate claims regarding future performance is rarely costless. In some cases it may be impossible to obtain the relevant information; one may not be able to generalize from existing information but instead must “experience” the energy performance as it is affected by one's own unique operating conditions, practices, or preferences.”

“**C. Asymmetric information and opportunism**—another aspect of the difficulties consumers face in evaluating the veracity, reliability, and applicability of claims made by sales personnel for a particular energy-efficient product or service. This barrier reflects the fact that sellers of energy-efficient products or services typically have more and better information about their offerings than do consumers. It also reflects the incentive that sellers have to provide misleading information.”

“**D. Hassle or transaction costs**—the indirect costs of acquiring energy efficiency are also closely related to information or search costs. These costs include the time, materials, and labor involved in obtaining or contracting for an energy-efficient product or service.”

“**E. Hidden costs**—unexpected costs associated with reliance on or operation of energy-efficient products or services. These costs could include additional operating and maintenance costs associated with energy-efficient equipment or additional staff costs associated with monitoring or servicing transactions (e.g., contractor supervision). They might also include additional costs resulting from the quality of installation. Many of these unplanned costs are incurred after the acquisition of an energy-efficient product or service.”

“**F. Access to financing**—the difficulties associated with the lending industry's historic inability to account for the unique features of loans for energy savings projects (i.e., that future reductions in utility bills increase the borrower's ability repay a loan) as distinct from the other factors affecting the evaluation of a borrower's credit-worthiness. In principle, accounting for energy-efficiency improvements funded by loans ought to result in lower borrowing costs.”

“**G. Bounded rationality**—the behavior of an individual during the decision making process that may seem inconsistent with a individual's goals... Such behavior is hardly irrational, in view of the potentially high search and information processing costs associated with trying to make every decision based on first principles, e.g., net present value. As a result, behavior is often described as rational in intention, but limited in its execution... This barrier is distinct from high search costs, performance uncertainties, and asymmetric information because more or better information

alone may be insufficient to change behavior. Instead, this barrier refers to the way in which individuals process and act (not necessarily logically) on whatever information they may have.”

“**H. Organization practices or custom**—organizational behavior or systems of practice that discourage or inhibit cost-effective energy-efficiency decisions. This barrier is closely related to bounded rationality but applies to organizations or social networks rather than to individuals. A good example is institutional procurement rules, policies, and practices that make it difficult for organizations to act on energy-efficiency decisions based on economic merit.”

“**I. Misplaced or split incentives**—institutional relationships which mean that the incentives of an agent charged with purchasing energy efficiency are not aligned with those of the persons who would benefit from the purchase. One example is in new construction where builders attempting to minimize first cost do not install higher-first-cost energy-efficiency features that would be valued by the future building owners who must pay the utility bills. In this case, the builder has no incentive to minimize utility bills she will not pay and every incentive to increase her profit by minimizing the first costs she does incur.”

“**J. Product or service unavailability**—the adequacy of supply. Unavailability of a product is different from high search costs that make it expensive for the consumer to locate a product or service. Unavailability is a market barrier created by the manufacturers and distributors of products or service providers that inhibits consumer demand. One result may be higher prices to reflect the fact that supplies are tight. Unavailability and high prices may be the result of collusive or anticompetitive practices to hold some products (or producers) off the market in favor of others that offer higher profit or other advantages (e.g. market share).”

“**K. Externalities**—costs that are associated with transactions, but which are not reflected in the price paid in the transaction. For example, environmental costs associated with electricity generation by fossil fuel are not incorporated into prices for electricity or fossil fuel use; these prices are too low in that they do not reflect the full cost to society of using these sources of energy. For markets to operate efficiently, transactions must incorporate full costs.”

“**L. Nonexternality mispricing**—other factors that move prices away from marginal cost. An example of this barrier arises when regulated utility commodity prices are set using ratemaking practices based on average (rather than marginal) costs.”

“**M. Inseparability of product features**—the difficulties consumers sometimes face in acquiring desirable energy-efficiency features in products without also acquiring (and paying for) additional undesirable features that increase the total cost of a product beyond what the consumer would be willing to pay for just the added energy-efficiency features alone. For example, energy-efficiency may be offered as an option on only the highest priced models in a product line, which also include a variety of other non-energy amenities.”

“**N. Irreversibility**—once a decision to purchase an energy-efficient product or service is made, it is often difficult to revise it in light of future information because aspects of the decision are irreversible (e.g., if future energy prices go down, one cannot get “salvage” insulation that has already been blown into a wall). Irreversibility is an attribute of many energy-efficient products and closely related to performance uncertainty.”