Cracking the TEAPOT: Technical, Economic, and Achievable Energy Efficiency Potential Studies

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Executive Summary

Energy system modeling and planning are inherently complex and subject to many uncertainties. Still, this critical and common exercise can provide important insights. There is growing understanding that energy planning should give as much consideration to demand-side resources like energy efficiency as it does to supply-side resources. Whether on the demand or supply side, modeling market dynamics across all customer classes over long periods of time is bound to be subject to complications and inaccuracies. Yet these projections ultimately influence related utility regulatory policy, which, in turn, influences utilities' expenditures on supply- and demand-side resources and the programs that deliver them.

In this report we focus on the development and role of energy efficiency potential studies. These studies have become an integral part of the energy system planning process in many states. The primary objective of our report is to better understand the nuts and bolts of these studies and how their various methodological approaches and assumptions influence energy efficiency potential estimates. We also examine how these methodologies, assumptions, and results may have changed since 2009 because of macroeconomic factors, building energy codes, appliance and equipment standards, market conditions, energy prices, and so on. Our goal is to give stakeholders a clearer understanding of how endogenous and exogenous factors can affect energy efficiency potential and, ideally, to help them come to their own conclusions about the veracity and integrity of these studies. It is important to realize that the value of potential studies depends on the effort and resources that go into them, and the assumptions—whether reasonable or constrained—that underlie them.

Motivations for Conducting Potential Studies

Since 2000 it has become more common for utilities to conduct studies in order to make the policy case for energy efficiency. This motivation is most relevant for cities, states, and utility service territories where there is not a lot of energy efficiency experience. Potential studies are usually conducted statewide as opposed to in a specific utility service territory. When utilities conduct studies to inform program planning, they use them in part to estimate the total costs of acquiring identified energy efficiency resources through program delivery, and also to decide how those costs should be allocated among energy efficiency measures and market segments. In other words, utilities can use potential studies to directly inform budget levels for energy efficiency programs, i.e., how much a program administrator—whether it be a utility, a statewide implementer, or a state energy office—would pay for them. Potential studies are also used in medium- and long-term integrated resource planning (IRP) to show the degree to which energy efficiency (demand-side) resources can be deployed to meet changing customer demand for energy as an alternative to supply-side investments.

Methodology

We reviewed and provide results for 45 publicly available studies published since 2009, nine of which were released by the American Council for an Energy-Efficient Economy (ACEEE). Based on our review, we discuss the various methodologies and assumptions typical of potential studies and how differences in these approaches can affect overall results. From the 45 studies, we selected ten from diverse authors and geographical areas for more thorough review. Our work included interviewing the authors integrally involved in developing the ten studies, and we provide the qualitative results of these interviews.

After the qualitative review, we delve into the quantitative results for the entire 45-study sample and briefly compare results to ACEEE's 2004 meta-analysis, *The Technical, Economic, and Achievable Potential for Energy-Efficiency in the U.S.: A Meta-Analysis of Recent Studies* (Nadel et al. 2004). Following that discussion, we explore some best practices in potential study design, provide some thoughts on the potential study of the future, and wrap up with our conclusions.

ANATOMY OF A POTENTIAL STUDY: QUALITATIVE FINDINGS

Our qualitative review explores the more critical assumptions and methodologies that underlie a typical energy efficiency potential study and briefly discusses how they can impact results. Even accounting for geographic, demographic, and economic differences, assumptions and methodologies can vary significantly across studies. This makes direct comparisons difficult. Furthermore, potential studies rely on a large number of inputs that can have significant impacts on results. Some of the more important inputs for which detailed information can be opaque or missing entirely include models for forecasting participation rates; assumptions about these rates; assumptions about incentive levels; the impacts of codes, standards, and emerging technologies; policy limitations; and utility avoided-cost assumptions. Many of these assumptions are inherent in the models used and in specific inputs, and as a result they are rarely disclosed or discussed, often for proprietary reasons. Lack of transparency about assumptions is a major issue for potential studies.

QUANTITATIVE FINDINGS

Overall we find that, for electricity, average annual maximum achievable savings range from 0.3% to 2.9% with a median of 1.3%. For natural gas, average annual maximum achievable savings range from 0.1% to 2.4% with a median of 0.9%. Nadel et al. (2004) found similar results, with a median for annual electric savings of 1.2%, and 0.5% for annual natural gas savings. This consistency implies that, for all the differences in methodologies and assumptions, states and utilities are still finding a considerable amount of cost-effective energy efficiency savings potential after more than ten years.

We also analyze the relationship between savings and study time period, savings and census region (to assess possible geographical differences), savings and participation rates, and savings and avoided costs. It appears that studies with a longer time horizon have lower average annual potential, but the correlation is weak. It does not appear that savings vary by geography: there was equal representation across the country for a given level of savings. We also find that savings are positively correlated with participation rates and avoided costs, although the small sample sizes result in a weak correlation.

BEST PRACTICES IN POTENTIAL STUDY DESIGN

We also provide some insight into best practices in potential-study design. For a number of reasons, potential studies are best suited to guide short-term rather than long-term energy efficiency program development and deployment. They can also be informative when incorporated into the IRP process and when used to develop utility savings targets. In the long term, the availability of energy efficiency resources has major implications for decisions to invest in and deploy generation resources, so a thorough quantification of energy efficiency can be very useful. Potential studies should also be sure to account for the full benefits of energy efficiency. There is a good deal of research on the non-energy benefits of energy efficiency, and while these benefits are hard to quantify, there is little doubt that the overall effect is greater than zero.

Transparency is also a major issue: a discouraging number of studies we reviewed are subject to at least some opacity. This lack of information is particularly confounding when it comes to the more influential elements of a study, including the assumptions behind maximum achievable and program/realistic potential scenarios, customer participation models, avoided costs, and emerging technologies. However, given the proprietary and competitively sensitive nature of many of the study elements, this opacity is unsurprising and perhaps unavoidable.

The Future of Potential Studies

Since the state of energy efficiency programs is always in flux for a variety of reasons, the assumptions and methodologies of potential studies should adapt accordingly. In addition, the economy is cyclical, and the majority of assumptions and inputs in a potential study are subject to economic forces: energy prices, customer participation, utility avoided costs, discount rates, and so on. Changes in particular assumptions can have a considerable impact on overall potential results.

Approaching studies from a program-design perspective is important, particularly in the short term. While most of the studies we reviewed had some programmatic focus, it was generally limited to identifying cost-effective efficiency measures or informing program budgets. Only a handful of studies contained any direct recommendations on how program design should reflect study results. Interest in programmatic implications is rising, however, and as states and utilities continue to expand their program portfolios, we are likely to see more potential studies being published to identify savings opportunities within the context of program design.

As more utilities use potential studies to inform program design, then studies should increasingly reflect the evolution of program delivery efforts and their potential to catalyze increased measure uptake. Program administrators are constantly testing and using new methods to design, market, and deliver their programs in order to bolster participation. In addition to taking into account the effects of enhanced program delivery, potential studies must also adjust their assumptions and methodologies to reflect changes in program design with respect to eligible measures. For example, building retrofit programs are beginning to focus on rebating whole-building efficiency improvements as opposed to simply providing downstream rebates for individual measures.

Conclusions

Energy efficiency potential studies have been common for decades, but since the year 2000 they have moved beyond their traditional use as a tool to inform program design. They are increasingly integrated into long-term energy system planning and used to inform regulatory policy. Potential studies will likely proliferate as more states and utilities without much experience expand their program portfolios. Thus it is important that stakeholders gain a better understanding of their mechanics and their limitations. In particular, they should understand how various methodologies and assumptions can affect savings potential, and how nuances make direct comparisons of studies difficult.

These limitations of potential studies certainly do not render them useless, but they do elucidate the need for greater clarity and transparency. Practically every study we reviewed was subject to some degree of opacity when it came to discussing important variables such as participation, emerging technologies, or avoided costs, whether intentionally or not. If potential studies are to continue to play a major role in energy system planning, stakeholders must be able to see and understand their methodologies in order to verify the veracity of the results. Transparency will lead to more active, constructive stakeholder discussions and more reflective assessments. The future usefulness of potential studies entirely depends on how much data and transparency their authors and their clients are willing to provide.

Introduction

In this report we focus on energy efficiency potential studies and their role in energy system planning. Potential studies are sophisticated analytical tools for identifying energy savings opportunities from demand-side resources. There is growing understanding that demand-side resources such as energy efficiency should be given the same consideration in energy system planning as supply-side resources. Energy system planning is a critical and common exercise that can provide important insights, but it is complex and subject to many uncertainties. The dynamic nature of our energy system requires demand-side energy planning to constantly develop new methodologies. Even so, it is still subject to the same fundamental issue as supply-side planning: models are not substitutes for reality.

Whether for demand- or supply-side resources, modeling market dynamics across all customer classes over long periods of time is complicated and inaccurate. In part this is because the assumptions that serve as inputs to these models are themselves complicated to develop and subject to inaccuracy and uncertainty. Despite these hurdles, utilities and stakeholders must invest considerable time and money to project the balance of supply- and demand-side resources required to meet customer demand decades into the future. They must project into the future in order to guide billions of dollars of investments today. These projections ultimately influence related utility regulatory policy, which in turn influences utilities' expenditures on supply- and demand-side resources and the programs that deliver them.

Potential studies have become an integral part of the energy system planning process in many states. In the 1980s, these studies were used predominantly for program planning, but once states ended their experiments with utility deregulation around 2000, studies have also become a popular tool for informing energy policy as well as program development and implementation. If these studies continue to play a significant role in energy system planning, both for policy and program development, stakeholders will need to understand their nuances. Seemingly minor assumptions can have major implications for a study's overall results, and policy objectives based on these results can remain locked in for years.

A wealth of research on energy efficiency potential studies is available as a guide to conducting and critiquing them. For example, the U.S. Environmental Protection Agency's *Guide for Conducting Energy Efficiency Potential Studies* is published through the National Action Plan for Energy Efficiency, now called the State and Local Energy Efficiency Action Network, or SEE Action (EPA 2007).[1] This publication provides information on conducting potential studies tailored to particular goals and scopes. *Ten Pitfalls of Potential Studies*, published by the Regulatory Assistance Project (RAP) and Energy Futures Group (EFG), identifies some of the most common and significant design elements and how they affect the interpretation of results (Kramer and Reed 2012). The American Council for an Energy-Efficient Economy (ACEEE) published a meta-analysis called *The Technical, Economic, and Achievable Potential for Energy-Efficiency in the U.S.: A Meta-Analysis of Recent Studies* in 2004

[1] http://www1.eere.energy.gov/seeaction/

and updated it in 2008 (Nadel et al. 2004; Eldridge et al. 2008). These latter papers focus on the results of studies published over the preceding five years; we will refer to them throughout this report.

The objective of the current report is to better understand the nuts and bolts of potential studies and the way in which their various methodological approaches and assumptions influence energy efficiency potential estimates. We also look at how these methodologies, assumptions, and results may have changed since 2009 due to macroeconomic factors, building energy codes, appliance and equipment standards, market conditions, energy prices, and so on. We examine results from 45 publicly available studies across the country and look more closely at the methodologies of ten studies from various states and utility territories. Our goal is to give stakeholders a better understanding of how endogenous and exogenous factors can affect energy efficiency potential studies, and, ultimately, to help them come to their own conclusions on the integrity of these studies.

Potential studies reflect the unique characteristics of their jurisdiction, and their role in energy planning depends on the goals of a state or utility, which can vary in both time and scope. Despite such differences, the growing import of potential studies means that stakeholders should expect them to show a high level of rigor and transparency and should scrutinize results when these expectations are not met. In this report we identify a number of concerns about the process of developing estimates of energy efficiency savings potential. Regardless of the role of a particular study and the goals of the planning process, these concerns should be addressed through a collaborative effort and an open, constructive discourse. Such efforts will help identify and document cost-effective energy efficiency opportunities and lay the groundwork for greater penetration of energy-efficient measures and systems to meet future customer demand.

We want to emphasize the fact that potential studies, like all energy models, are useful tools for short-term program planning, but they are significantly less reliable for quantifying potential savings in the long term. Ultimately, these studies are a product of the effort and resources that go into them and the assumptions—reasonable or constrained—that underlie them.

Motivations for Conducting Potential Studies

There are various motivations for conducting energy efficiency potential studies. Understanding the motivation behind a study may give some insight into its methodology and assumptions and, ultimately, assist in interpreting the results.

WHY DO A POTENTIAL STUDY?

Utilities most commonly conduct energy efficiency potential studies to meet regulatory requirements related to program planning. Although many experienced states use these studies to guide their investments, they appear to be most prevalent in states that are ramping up their efforts and need to identify prudent rates of growth. Potential studies are also useful as part of the long-term integrated resource planning (IRP) process. Below we list several of the justifications for investing in these studies:

- Provide the analytic basis for efforts to treat energy efficiency as a resource equivalent to supply-side resources
- Quantify the energy efficiency resource for system planning
- Identify and prioritize market sectors and energy-efficient technologies that offer the highest resource opportunities
- Inform the development of utility savings targets
- Determine appropriate and adequate funding levels for delivering energy efficiency programs
- Inform energy efficiency program design in order to achieve near- and long-term savings potential
- Reassess energy efficiency opportunities as conditions change

Since 2000, it has become more common for utilities to conduct studies in order to make the policy case for energy efficiency. This motivation is most relevant for cities, states, and utility service territories where there is not a lot of energy efficiency experience. Studies are usually conducted statewide rather than in a specific utility service territory. When utilities conduct studies to inform program planning, they use them in part to estimate the total costs of acquiring identified energy efficiency resources through program delivery and how those costs should be allocated (e.g., administrative costs versus customer incentives). In other words, potential studies can be used to directly inform priorities and budget levels for energy efficiency programs. They can indicate how much a program administrator (which can be a utility or a third-party implementer—statewide or within a utility service territory) would pay for the programs. Potential studies are also used in medium- and long-term IRP to show the degree to which changing customer demand for energy can be met by demand-side resources like energy efficiency as an alternative to supply-side investments.

SEE Action's *Guide to Conducting Energy Efficiency Potential Studies* includes a graphic continuum of these various potential study goals that plots the level of detail against the cost and length of time needed for completion (figure 1). Not surprisingly, studies whose scope involves detailed planning and program design require a level of detail that in turn requires a high level of time and investment.

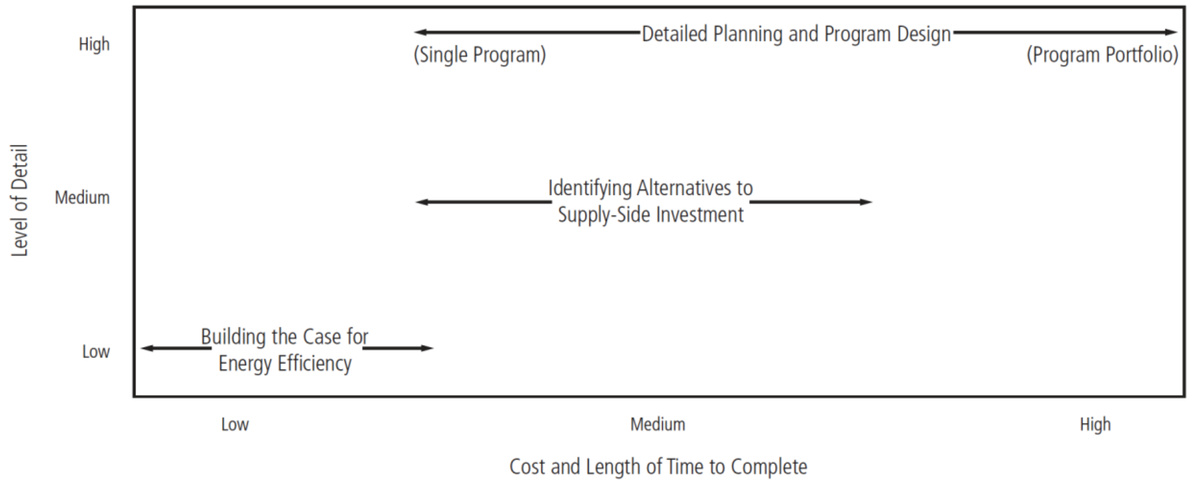

Figure 1. Considerations for conducting potential studies. *Source:* EPA 2007.

WHO TYPICALLY COMMISSIONS STUDIES?

The impetus to conduct a potential study can come from a variety of stakeholders. Often the genesis of a study is rooted in regulatory or public policy.

Regulatory commissions may require utilities to conduct energy efficiency potential studies as part of the systemwide planning process. Some commissions require studies to be updated regularly, typically every three to five years. The Iowa Utilities Board, for example, requires its investor-owned utilities to file potential assessments every four years. Commissions in states with a strong commitment to energy efficiency may require potential studies as a way to regularly reassess potential for planning purposes (e.g., as part of the IRP process) or to help inform the setting of utility savings targets.

Utilities commission potential studies for planning purposes, typically in response to a regulatory requirement, or in their own interest. For example, Arkansas's investor-owned utilities requested a potential study after the Arkansas commission suggested specific energy efficiency targets. Potential studies give utilities an opportunity to assess the volume and types of energy efficiency potential within their service territory, often in the context of their ability to achieve mandated savings targets. Studies also help them understand the costs and benefits of capturing that potential. Utilities can use cost estimates to inform program budgets, which are reported and filed in demand-side management (DSM) plans.

State governments commission studies to guide energy policy or to make the policy case for increasing energy efficiency investments, usually with the goal of spurring economic development. Directives may originate through an executive order, the state legislature, or state energy offices.

WHO TYPICALLY CONDUCTS STUDIES?

The great majority of energy efficiency potential studies are conducted by third parties such as private consulting firms and nonprofit research institutions. These groups typically respond to requests for proposals (RFPs) issued by a state or utility, though in the case of a nonprofit research institution like ACEEE, the request may come from the institution's funders. Some studies conducted for utilities are not publicly available.

Methodology

We reviewed and provide results for 45 publicly available studies published since 2009, nine of which were published by ACEEE. We identified the 45 studies from information provided by contacts at various consultancies and nongovernmental entities. This roster of studies is certainly not exhaustive, and there are likely many potential studies that are not publicly available. As our contacts cover all U.S. regions and states, the studies are fairly diverse, although additional studies would have added further perspective on the topics we explore. Twenty-three studies focus only on electricity, 19 focus only on natural gas, and 18 focus on both electricity and natural gas.

From these 45 studies, we selected ten from diverse authors and geographical areas and reviewed them more thoroughly. Our work included interviewing the authors integrally involved in developing the selected studies, using a set of questions which we gave to the interviewees beforehand. For a variety of reasons such as open utility regulatory proceedings, we were unable to discuss with interviewees some of the publicly available studies that we reviewed. The report itself does not directly attribute remarks or quotations to any of the interviewees, since many of their responses, particularly on the future of potential studies, might be considered speculative and not representative of their respective organizations. Overall, the report does not publish any information that is not publicly available.

In the following section we provide the qualitative results from the interviews as well as analysis from our independent review of all 45 studies. We also discuss the various methodologies and assumptions typical of potential studies and how differences in these approaches can affect overall results. After the qualitative review, we delve into the quantitative results for the entire 45-study sample. We conclude with a discussion of the qualitative and quantitative results and our thoughts on the future of potential studies. Appendix A contains case studies of the ten selected potential studies as the background for our analysis.

Anatomy of a Potential Study: Qualitative Results

In this section we discuss some of the more critical assumptions and methodologies that underlie a typical energy efficiency potential study. We also briefly discuss how these factors can affect results. Assumptions and methodologies can vary significantly across studies even accounting for geographic, demographic, and economic differences, rendering direct comparisons difficult. Within the context of a specific study, however, understanding these nuances allows the reader to gauge how accurately a study reflects existing potential. By examining these issues individually, our goal is to impart to readers the innate complexity and uncertainty of modeling and the fact that potential studies ultimately are a reflection of their assumptions, as well as the time and effort invested in them generally.

Our areas of focus are informed by RAP's *Ten Pitfalls of Potential Studies* (Kramer and Reed 2012), which covers these issues in much greater detail. In our discussions we include interviewee perspectives on how these assumptions and methodologies have changed over the last five years in response to a crippling economic recession, a historic drop in natural gas prices, falling utility avoided costs, and other factors. ACEEE's meta-analysis in 2004 also considered potential studies published within the preceding five years, so focusing on the previous five years is prudent at least for the sake of continuity.

THE VARYING LEVELS OF POTENTIAL

Potential studies typically examine three to four different levels of energy efficiency potential, each of which conveys a different perspective on the availability of resources within a defined geographic area. Definitions of these potential levels can vary across studies and, as an added complexity, they are not always explicitly defined. Here are definitions as given by EPA (2007), followed by an in-depth discussion of each level.

Technical potential represents "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 energy efficiency measures." Only 24 of the studies we reviewed reported results for the technical potential analysis. Definitions of technical potential generally do not differ across studies, though the degree to which emerging technologies are included does.

Economic potential represents "the subset of technical potential that is economically cost-effective as compared to conventional supply-side energy resources." Cost effectiveness (at the measure level) is usually evaluated using the Total Resource Cost (TRC) test, although a handful of studies evaluated economic potential using the Societal Cost Test (SCT). We discuss benefit-cost tests in further detail below. Twenty-six of the studies we reviewed reported results for the economic potential analysis. Two of these studies did not define the cost-effectiveness test used in the analysis. They simply noted that measure cost effectiveness was determined by comparing the levelized cost of saved energy to utility avoided costs. These two studies also had the lowest ratio (%) of economic to technical potential, so it is possible that they assumed more restrictive utility avoided costs akin to those used in the Rate Impact Measure (RIM) test.

(Maximum) achievable or market potential represents "the amount of energy use that efficiency can realistically be expected to displace assuming the most aggressive program scenario possible." Maximum achievable and market potential analyses are designed to reflect savings potential given market and programmatic barriers (hence the frequent use of the word "realistic" in studies' definitions). Achievable potential is often analyzed in at least two different scenarios. The primary variation is the level of financial incentives or rebates offered to participants, which typically max out at 100% of the incremental cost of the efficient measure. Every study we reviewed estimated maximum achievable or market potential, although three studies in the Northwest focus on a metric for potential that is

slightly different from traditional achievable potential estimates (see below). Only seven of the studies we reviewed, mostly by one author, constructed a maximum achievable scenario that did not assume incentive levels set at 100% of incremental costs.

Program, realistic, or constrained achievable potential is defined as a subset of the (maximum) achievable potential that further limits energy efficiency potential by taking into consideration market or programmatic barriers or constraints such as program budget caps or implementation issues. Ten of the studies we reviewed include one of these scenarios. Most of the studies also account for program barriers in their analyses of maximum achievable potential; here is an example where lack of clarity regarding assumptions can create confusion. Additionally, estimates of program or realistic potential rarely assume incentive levels of 100% of incremental cost. This is because the vast majority of programs do not offer customers incentives of that magnitude.

While these are the most common levels of potential, our review uncovered an additional type: *achievable technical potential.* We encountered this type only in studies focusing on utility service territories under the jurisdiction of the Northwest Power and Conservation Council (NPCC). This additional type is for long-term planning purposes, where the NPCC assumes that 85% of technical potential is achievable over a 20-year planning horizon. Achievable technical potential accounts for market barriers but does not take into account cost effectiveness.[2]

Assumptions made within each potential type can have a significant impact on the final results, though interviewees noted that methodologies for estimating technical and economic potential are well established. The heaviest scrutiny is usually reserved for the assumptions and methodologies for estimating achievable and program potential. For example, interviewees noted that assumptions about market and program barriers are hard to quantify and often left to the professional judgment of the analyst. Given this apparent subjectivity, it is common for these assumptions to vary noticeably across entities and analysts.

Deconstructing Definitions of and Assumptions About Potential

Technical potential is limited by the types of commercially available and emerging technologies that the analyst or commissioning entity includes in the analysis. Stakeholders generally agree upon what is considered commercially available technology. Yet the degree to which emerging technologies is included varies considerably across studies. This is primarily due to different perspectives on their costs and savings potential and how those vary over time. It is also due to differences in budgets that predicate how much effort can be devoted to assessing emerging technologies.

The analysis of *economic potential* determines the cost effectiveness of individual energy-efficient measures for the purpose of determining which measures are considered for the

[2] However the cost effectiveness of achievable technical potential can be identified when avoided costs are known because it can be presented in an economic merit order from the lowest cost ($/kWh) to the highest.

analysis of achievable potential. All of the studies we reviewed used either the TRC test or the SCT to estimate measure cost effectiveness. With the TRC test, the cost effectiveness of measures is determined vis-à-vis a utility's avoided costs (discussed further below). Assumptions about avoided costs, then, have major implications for the final economic potential estimates. On the other side of the equation, assumptions about individual energy efficiency technologies or measures also have major implications for cost effectiveness. These assumptions include measure lifetime (in years), incremental costs, per-unit savings, and non-energy benefits (NEBs)[3].

Achievable potential, particularly when preceded by "maximum," is usually defined (whether explicitly or implicitly) as the upper limit for cost-effective energy efficiency savings potential given market and program barriers. It is often analyzed through multiple scenarios that vary by assumed incentive levels: 21 of the studies we reviewed included multiple achievable potential scenarios. Since achievable potential is intended to reflect realistic savings opportunities, these estimates tend to serve as inputs in developing related regulatory policy, utility planning, and program efforts.

All but two of the 45 potential studies we reviewed provided a qualitative definition of achievable potential and the assumptions behind its measurement. However, the vast majority of studies excluded quantitative information on some critical factors in their definition. Approximately a half-dozen studies did not provide information on the level of incentives assumed. Also, almost no studies quantified how market and program barriers limit potential (e.g., X% decrease in participation, Y% increase in administrative costs). In fact, interviewees noted that the quantitative impact of market and program barriers is usually left to the discretion of the study author (and client) and is almost always subjective. A lack of transparency when defining achievable potential can be especially confounding because, by virtue of being labeled "maximum," stakeholders assume that this value is truly the upper limit of cost-effective energy efficiency potential in the area.

Assumptions can become even murkier when studies go a step beyond achievable potential to estimate *program, realistic, or constrained potential*. Some quantitative limitations that are not taken into account in the maximum achievable scenario can be defined explicitly, such as mandated program budget caps. However, some studies include limitations that are not explicitly defined, such as "barriers to customer acceptance." In the latter example, stakeholders are at a loss to determine the degree to which these assumptions affect final results. Ten of the studies we reviewed explicitly included either program, realistic, or constrained potential scenarios. Five of these studies were conducted by the same author, and in four of the five studies, the labeling was changed to "achievable—low potential," despite the definitions being consistent across all five studies.

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[3] Non-energy benefits, which have also been labeled "non-energy impacts" or "other program impacts," are those benefits and costs that are not typically included in utility estimates of avoided costs, which include "other fuel savings," or savings of the fuel not provided by the utility in question. See Woolf et al. 2012 for detailed information on "other program impacts" from utility, customer, participant, and societal perspectives.

It appears that this final type of potential level is simply an alternative to achievable potential with multiple scenarios (e.g., low, mid, high). The exception is that, in addition to varying the assumed incentive levels, market and program barriers are varied as well. However, most studies that we reviewed accounted for these barriers in the maximum achievable potential scenario(s). So it is difficult for readers to discern the differences among these levels of potential, especially when there is no additional information provided on the quantitative assumptions.

As an example, here is a definition of (maximum) achievable potential from a recent study:

> Maximum Achievable Potential [MAP] estimates customer adoption of economic measures when delivered through efficiency programs under ideal market, implementation, and customer preference conditions and an appropriate regulatory framework. Information channels are assumed to be established and efficient for marketing, educating consumers, and coordinating with trade allies and delivery partners. Maximum Achievable Potential establishes a *maximum target for the EE savings that an administrator can hope to achieve through its EE programs and involves incentives that represent a substantial portion of the incremental cost combined with high administrative and marketing costs* (emphasis added).

In this study the realistic achievable potential is defined as a subset of maximum achievable potential, where:

> Realistic Achievable Potential [RAP] reflects expected program participation given barriers to customer acceptance, *non-ideal implementation conditions* (emphasis added), and limited program budgets. This represents a lower bound on achievable potential.

It is helpful for a potential study to account for market and programmatic barriers such as "non-ideal implementation conditions" (e.g., a lack of contractor infrastructure or a weak economy) and other related variables. This is because program administrators and stakeholders need to understand the conditions that facilitate the effective deployment of energy efficiency programs. However, based on feedback from interviewees and ACEEE's own experience, these types of assumptions are extremely hard to quantify and left to the best judgment of the analyst and the reader. Still, there is a lot of variation and ambiguity in these definitions across studies. Readers must be provided better information to be able to comprehend how these assumptions quantitatively impact savings potential or, at the very least, to understand the basis of these assumptions.

METHODOLOGIES AND ASSUMPTIONS

Potential studies are packed with assumptions that can have significant impacts on potential estimates, though the impacts are not always made apparent. Many of these assumptions are inherent to the models used and to specific inputs. As a result they are rarely disclosed or discussed, often for proprietary reasons. Lack of transparency about assumptions is a major issue endemic to potential studies. There is a lot of variation in the degree of transparency across studies, which makes comparisons across studies difficult, and detailed critiques of the studies themselves by stakeholders burdensome. As we will discuss below, a lack of transparency is not necessarily an attempt to obfuscate results or the fault of any one party. For many assumptions, analysts must employ their best professional judgment for a variety of reasons, such as budget constraints or a lack of data. Ultimately what is most important is that, when these circumstances arise, the studies provide enough information to enable readers to use their own best professional judgment regarding the veracity of the results.

This section addresses a few of the relatively more significant assumptions and methodologies vis-à-vis overall potential estimates. Much of this discussion was informed by interviews with authors of potential studies as well as conversations with other industry experts. Our goal is to educate readers on how changes in assumptions can impact potential estimates and how to discern the rigor of the assumptions themselves.

Participation Rates

Modeling customer adoption rates of individual energy-efficient measures (which we refer to as customer participation rates but can also be labeled as customer acceptance rates) is a difficult but unavoidable task inherent in all potential studies.[4] Essentially, customer participation is a function of marketing, economics, and customer segmentation, the effects of which are extremely difficult to model accurately over time. Interviewees noted that significant time and resources can be dedicated to modeling participation without any noticeable effect on precision. In fact, modeling how the market (i.e., customers) reacts to various energy- and program-related stimuli (e.g., prices, incentives, and marketing) is the most imprecise aspect of any potential study.

Some analysts will invest resources to engage in primary research with the intention of more accurately reflecting existing conditions within the defined geographic area or utility service territory. This is timely and costly, so the degree of primary research conducted is heavily dependent upon the available budget for a study. Primary research on participation collects relevant data (e.g., through customer surveys) to ascertain how customer purchasing decisions are influenced, usually relative to the costs of an energy-efficient measure and any available incentives, which is known as a customer's "simple payback."[5] Estimates of payback are then used to develop "technology adoption curves" or "payback acceptance curves." These curves portray how customer purchasing behavior reacts to these economic inputs (though self-reporting on payback acceptance may not reflect actual purchase decisions). In these types of modeling exercises, participation rates are an output. However, studies typically do not provide enough information on the development of payback acceptance data for readers to assess their accuracy or relevance.

Other entities will forgo the expense of primary research and model participation using generic adoption curves or program delivery experience from other jurisdictions. For

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[4] ACEEE is currently engaged in research on participation rates, in particular the program design elements that lead to high rates of participation. The study is tentatively scheduled to be released in the fall of 2014.

[5] ICF International defines "simple payback" in one of its studies as "the dollar amount invested by the customer in the measure (the incremental cost minus the incentive) divided by the annual bill savings due to the measure, expressed in months or years" (ICF 2013).

example, analysts can reference utility energy efficiency program (ex-post) evaluations to understand historical experience and extrapolate that experience to inform participation models.[6] This approach has the virtue of using data on actual adoption rates and not self-reports of prospective adoption rates. It is also not uncommon to take a hybrid approach, where primary research on participation takes into account past experience in order to weight the results of the primary research.

ACEEE has published 14 statewide energy efficiency potential studies over the past eight years, nine of which are included in this report. For each study we were asked not only to estimate the volume of achievable potential within a state, but also to suggest state- and utility-funded energy efficiency programs that could capture that potential. For our clients, our discussion of programmatic opportunities was as integral to the analysis as the quantification of potential. ACEEE's program potential analyses use historical and projected program data from various jurisdictions, including program delivery experience in the state for which the study is being conducted. This approach includes assumptions about program administrative and incentive costs, as well as participation rates. Budgets for our studies have not allowed for detailed modeling efforts, however, particularly in regard to modeling technology adoption curves in order to inform estimates of participation over time. The effect of limited budgets on potential studies is an underappreciated factor, one that we discuss further in a later section.

Research has shown, however, that a customer's willingness to invest in a measure is not completely driven by economics but often by other considerations. This phenomenon is known as the announcement effect. Loran Lutzenhiser, a leading researcher on the interaction of behavior and energy consumption, notes: "Economics can supply normative guides regarding when investments would be economically desirable, but it tells us little about how persons actually make economic decisions" (Lutzenhiser 1993).[7] For example, customers may be influenced more by successful marketing efforts or aggressive stocking practices for energy-efficient products than by incentives. Issues such as health and sustainability commitment also factor into customers' investment decisions about energy efficiency, and these vary widely across customers. Research by the Alexandra Institute points out that, in order to influence user-driven optimization and reduction of energy consumption in the home, "We have to investigate the reasons behind people's lifestyle and consumer behaviour and the underlying motivations and barriers that may either support or change their behaviour . . ." (Entwistle 2009).

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[6] It is important to note, however, that participation is generally correlated to program maturity, assuming effective marketing and outreach efforts. For example, actual program participation during a program's start-up period is a poor indication of the long-term potential for participation, but over time participation should increase if there is a concerted marketing and outreach effort. With this in mind, studies that rely on secondary research must strive to be transparent about the references for their assumptions.

[7] For a detailed analysis of behavioral assumptions in the context of potential studies, see *Behavioral Assumptions in Energy Efficiency Potential Studies* (Moezzi et al. 2009).

Several interviewees noted that, as an industry, we tend to undervalue the behavioral influence of persistent investments in marketing and education. Interviewees shared that marketing and education impacts are in fact essential inputs into their models; one noted that marketing budgets are a primary driver of its model, adding that greater marketing investments generally lead to greater participation. Quantifying the impacts of marketing and education efforts is difficult, however, so often analysts must use their best judgment. Most of the studies we reviewed report potential results relative to the incentive levels assumed within a scenario, with little mention of marketing. But if models of participation are dependent upon assumptions of marketing and education impacts, as interviewees suggested they are, then studies must do a better job of elaborating on these assumptions and how they are incorporated into the models.

Participant Incentive Levels

Financial incentives are an important driver in garnering customer participation in energy efficiency programs and, as we noted above, a primary input into modeling customer participation rates. Potential studies usually consider various levels of customer financial incentives in order to convey how customers' willingness to pay for energy efficiency measures changes relative to the incentive amount. In practice, incentives generally comprise a significant portion of program budgets, often above 50%, depending on the maturity of the program and the types of measures that are eligible through the program (Molina 2014). Assumptions about incentive levels are incorporated into analyses of achievable potential, thereby answering these questions: Given estimates of cost-effective (economic) potential, to what degree do customers need to be incentivized to participate (in purchasing an energy-efficient measure)? What levels of achievable potential can be realized as a result of those levels of participation?

Although we found a few exceptions in our sample, the great majority of potential studies include a scenario that estimates maximum achievable potential, which usually assumes that incentives cover 100% of the incremental cost of a measure. However, incentives equivalent to 100% of incremental costs are not representative of standard program design practices. So most studies will include at least one other scenario that assumes lower incentive levels more in line with existing program design. These are usually in the range of 25%–75% of incremental costs.

We noted above that incentives are not the only factor that spurs customers to invest in energy efficiency. Most potential studies, however, assume that incentives are the primary factor, at least relative to how participation models are developed. We heard from interviewees that marketing and education efforts are also incorporated into customer participation rate models as a key driver of participation. Yet, by defining maximum achievable potential as a scenario where incentives are maxed out at 100% of incremental costs, studies place a theoretical upper bound on potential based solely on economics. This is a troublesome message because it negates the impacts of marketing and education efforts and implies that there are no additional savings to be realized beyond the maximum amount estimated in the study.

Of the studies we reviewed, 19 included just one achievable potential scenario (i.e., no variation in the assumptions about incentive levels).[8] Of these 19, five studies (including three conducted by ACEEE) did not define assumed customer incentive levels in the achievable potential analysis. In all but one of the ACEEE studies, it is not clear whether incentives were set at 100% of incremental costs or lower.[9] The two non-ACEEE studies reported average annual savings toward the low end of the savings range we identified (which we report in our section on quantitative results). But the degree to which overall results are affected by assumed incentive levels is difficult to determine.

Building Energy Codes, Appliance and Equipment Standards, and Emerging Technologies

Building energy codes and appliance and equipment standards (codes and standards) generally raise the baseline level of energy efficiency within a defined area. This reduces overall savings potential by decreasing the opportunities for the deployment of energy-efficient measures from utility energy efficiency programs.[10] The degree to which codes and standards reduce potential savings for programs depends on assumptions as to when these codes and standards become effective and the certainty of the savings they will create. It also depends on assumptions about emerging technologies and their potential to create additional savings opportunities that counter the upward pressure of codes and standards on the technology baseline. On the other hand, because codes and standards generally result in participation rates approaching 10%, they increase the overall amount of energy efficiency that is achievable. And in some cases, utilities can receive credit for efforts to support codes and standards (Misuriello and Kwatra 2012).

Potential studies incorporate savings from codes and standards in three ways:

1. Savings are directly incorporated into the baseline sales forecast, thereby lowering forecasted sales in each year relative to business as usual.
2. Savings are incorporated at the measure level in the technical potential analysis, as a limit on the applicability of a measure to reflect the existing saturation of an efficient measure.
3. Savings are reported as additive to and independent of overall potential results and therefore not reflected in the baseline sales forecast.

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[8] Three of the 19 studies were focused on the Northwest, which conducts potential studies for long-term system planning and measures "achievable technical potential" in terms of average megawatts (aMW) with no regard for costs. By not taking costs into account, there is no need for multiple scenarios. So really only 16 studies included one achievable potential scenario when, theoretically, multiple scenarios could have been included.

[9] ACEEE models participation based on rates achieved by programs in the field, and incentives in those programs vary. Our assumptions regarding participation rates implicitly assume effective marketing.

[10] The baseline level of energy efficiency is the saturation of energy-efficient products within a defined geographic area, which is incorporated into estimates of technical potential in terms of a measure's applicability, given as a percentage, in order to account for customers that have already adopted the efficient measure. It is slowly becoming more common for utilities to become involved in promoting codes and standards, which provides them with opportunities to earn savings credit through their efforts.

Savings are usually incorporated at the measure level, although the impact of codes on an individual measure is extremely difficult to parse. So analysts will often rely on utilities for assumptions on savings from codes (since codes are adopted by state or jurisdiction). It is generally assumed in potential studies that equipment subject to standards is replaced on burnout (i.e., at the end of its useful life).

The impact of codes and standards on savings depends on how policies are incorporated into the baseline. For example, codes and standards policies that are already on the books have a high degree of certainty about related savings. The impacts of these policies on savings potential are usually felt the greatest in the early years (usually three to five years). States and jurisdictions do not adopt new codes more frequently than triennially,[11] while the U.S. Department of Energy does not issue new standards for equipment more frequently than every five years.[12] Savings from codes and standards that are either in the process of being adopted or have not yet been adopted have a lower degree of certainty, as these policies usually occur in the medium and long term (i.e., greater than five years). Still, in addition to short-term savings from policies on the books, studies should strive to incorporate savings from expected policies. This is because the timing and expected savings are usually well understood, and it is infrequent, albeit possible, that expected policies are reversed or not enforced.

Many of the studies we reviewed failed to adequately explain their assumptions about the timing and magnitude of expected savings from codes and standards. This is a problem given their potentially profound impact on the technology baseline. Still, many studies did elaborate on their assumptions on codes and standards, though the most detailed information on the potential impacts was provided relative to federal lighting standards.

LIGHTING STANDARDS

Program administrators often claim that codes and standards tend to eat up a considerable chunk of "low-hanging fruit." This makes it more costly to achieve additional savings through their programs, primarily because of federal lighting standards. However, these claims underappreciate the rate at which technology prices fall and the rate at which emerging technologies can supplant those lost savings.[13] Research on the net effect on

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[11] Visit http://energycodesocean.org/code-status for more information on state adoption of building energy codes. Approximately a dozen states have also adopted their own standards; however, most of these have been preempted by federal standards. California is the most prolific when it comes to state standards, and many of the standards it has established have been used to establish federal standards on the same products.

[12] Visit http://energy.gov/eere/buildings/standards-and-test-procedures for more information on the development of federal appliance and equipment standards. The Appliance Standards Awareness Project (ASAP) also maintains a table that shows which types of equipment are subjected to federal standards, the date of the previous standard, and the expected date for the release of the updated standard: http://www.appliance-standards.org/national.

[13] The incremental costs of light-emitting diodes (LEDs), for example, have dropped significantly in the last several years, by about 75% (http://www.eia.gov/todayinenergy/detail.cfm?id=15471). Therefore studies that assume high incremental costs for LEDs, given the vast amount of lighting potential that studies are reporting, are underestimating savings potential.

savings of codes and standards and emerging technologies is limited. But the research that exists shows that new technologies and program delivery strategies can often more than offset the loss of savings potential from codes and standards (Geller et al. 2014). Interviewees noted that the incorporation of federal standards, particularly lighting, is treated inconsistently across studies, though they offered no elaboration or examples of how this is done, nor did we ask. Again, most studies that we reviewed did not report savings from standards such as lighting. So it is difficult to understand how states and utilities are accounting for standards and their impact on savings potential.

Nonetheless, the majority of studies that we reviewed found considerable potential savings from lighting, even after the effects of federal lighting standards were incorporated, in the range of 8%–77% of total maximum achievable potential savings for the residential sector and 34%–63% for the commercial sector (see table C1 in Appendix C).[14] By definition, achievable potential savings are cost effective. So it is clear that the majority of state and utilities continue to view investments in efficient lighting as a source of huge cost-effective savings, particularly investments in specialty compact fluorescent lamps (CFLs) and light-emitting diodes (LEDs). Clearly analysts are at odds about lighting savings potential in the residential sector, given the vast range. But the median and average savings for lighting are still around 30% of total maximum achievable potential savings across the studies that reported these data. There is less variation in maximum achievable potential savings from lighting in the commercial sector, so analysts seem to agree that savings from commercial lighting will continue to comprise a large portion of potential for the foreseeable future.

EMERGING TECHNOLOGIES

Assumptions about emerging technologies (ETs) can have a noticeable impact on potential results, particularly for those studies that consider long-term savings potential (i.e., ten years out or more). Many studies we reviewed include savings from ETs, but only a half-dozen or so are transparent about the measures they assume to be emerging. Where savings potential from ETs is provided, however, the impacts are considerable. Cadmus' 2012 study for the Iowa Utility Association, for example, finds that ETs could increase electric market potential (i.e., maximum achievable potential) by up to 3%, or 0.3% additional achievable savings annually over the ten-year study period (Cadmus 2012). KEMA's 2010 study for Xcel Energy Colorado finds that economic potential increases by 24% when ETs are included. Of these, 13% could be achieved through programs over an 11-year period (KEMA 2010). Clearly the savings potential for ETs is substantial enough that it should not be ignored.

For the most part, if studies report that ETs are included, it is difficult to determine which measures they assume to be emerging, how prices change over time, and the year in which they are assumed to become cost effective. There is also considerable variation in the number of additional measures included across studies. This variation in part is dependent

[14] 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.

on how an ET is defined; several studies that included new measures relative to a previous study (i.e., commercially available measures that were not included previously) lumped these new measures in with ETs. Interviewees noted that the degree to which ETs are included also depends on a client's needs or goals: if the goal of a potential study is to inform program design in the near term, it is unlikely that the study will include many ETs at all. However, if the goal of a potential study is more for long-term planning and to ascertain the maximum energy efficiency resources available, then the study likely will (and should) include at least some ETs.

There are approaches to modeling ETs that authors should consider so as to include at least some minimum amount of savings potential. Where time and resources are limited, authors could include adders for ETs—as is done with adders to account for NEBs—to acknowledge that the impacts are greater than zero. Some research would be needed to inform what constitute reasonable assumptions, given that our two examples above found fairly disparate impacts from ETs on savings potential. Studies can also choose a certain number of measures from a vetted list of ETs that are considered to have significant potential in the near future. ACEEE will be publishing a report in 2015 on almost two dozen ETs and their savings potential. Such measures that authors should consider strongly include residential LEDs, combined heat and power (CHP) systems, conservation voltage reduction, advanced commercial lighting design, whole-building retrofits, and strategic energy management for large commercial and industrial buildings.

For the most part, potential studies are not clear about how codes and standards and ETs are incorporated into analyses from a quantitative perspective. We can assume that most potential studies at least pay lip service to these impacts on savings potential. But there are often scant data on the magnitude of these impacts. For stakeholders to understand the programmatic implications of codes and standards and ETs, the magnitude of the impacts must be conveyed clearly. For instance, if building energy codes are expected to limit potential savings in the future and this could jeopardize a utility's ability to meet its targets, then stakeholders may want to consider a utility code support program that will enable utilities to take credit for some savings from these codes. But first the magnitude of the impact has to be understood. If federal lighting standards indeed create free-ridership issues and limit savings potential, then the magnitude of the impact must be understood so that programs can be designed to maximize savings from the potential that does exist. As we noted, the savings are still considerable given the potential reported in the studies we reviewed. In fact, the industry would be well advised to pursue research that attempts to quantify the average impact of codes and standards and ETs on savings potential. Then we could have more effective discussions on how to address these issues.

Policies and Other Assumptions Limiting Potential

It is common for state legislatures or regulatory commissions to develop sets of rules or policies that guide utility investment in energy efficiency programs. These usually consist of energy efficiency savings targets as well as caps on them or on rate impacts, program budgets, or program spending. Other mechanisms that influence savings potential include rules on the types of costs and benefits that can be considered (which can prevent certain measures from being deemed cost effective) and opt-out policies for industrial customers.

The justification for these rules is often labeled as economic: public entities are keen on constraining potential rate impacts for all customer classes, or the state has a goal of stimulating economic growth through energy efficiency. However the justification can also be program related: potential studies are often used to inform program budgets, so authors will craft a scenario to reflect any existing budget limitations (caps) in order to examine savings potential within that context. Ultimately, these policy tools can limit energy efficiency investments and therefore place a ceiling on the level of savings that can be captured by programs.

Ten studies in our sample include public policy limitations whose impacts on energy efficiency potential are estimated through program or realistic achievable potential analyses.[15] Several of these studies explicitly define the limitations on spending imposed by legislative or regulatory authority, such as Illinois's budget cap of approximately 2% of annual customers' total electric costs. Many included "limited program budgets" in the definition of these types of achievable potential without elaborating on how these were quantified and incorporated into the analysis. Limitations such as these are misleading and contrary to the purpose of potential studies, if the purpose is to identify the maximum cost-effective achievable potential available. Even if the policy limitation is well defined, such as in Illinois' budget cap, it is still useful to include an uncapped scenario so policymakers can evaluate savings potential in both contexts (perhaps to determine if changes to a cap are justified).[16] Regardless, if energy efficiency is truly considered an energy system resource, then it should be evaluated as such and not be subjected to limits on spending, particularly if their definition and impact is unclear. If such policy limitations are imposed, then they should be explicitly defined in order to transparently convey the assumptions under which savings potential is assessed.

Other, nonpolicy-related limitations are often assumed in estimations of both achievable and program potential. Yet it is not always clear how these limitations are incorporated. As discussed earlier, researchers are required to make assumptions about market and programmatic conditions that may create barriers—or spillover—that will affect participation and, ultimately, savings potential.[17] As an example, we discussed "non-ideal implementation conditions." Assumptions like these that are not easily quantifiable are usually left to the best judgment of the analyst. How the analyst decides to handle these assumptions should be clearly described.

Limited Project Budgets Constrain Primary Data Collection in a World of Limited Data

Budget limitations are a common and underappreciated barrier to developing a comprehensive potential study. Conversations with interviewees revealed that limited budgets restrict the amount of primary research analysts can conduct with respect to the

[15] Policies that dictate the cost and benefits that can be included are generally incorporated at the measure level in economic potential analyses.

[16] ICF's study for ComEd in Illinois included an uncapped maximum achievable potential scenario.

[17] Spillover refers to any increased adoption of energy-efficient technologies that can be attributed directly to a program but not to the size of the incentive the program offers (Kramer and Reed 2012).

scopes of modeling and data collection, as well as the overall scope of the study. Limited budgets for primary data collection are used instead for benchmarking end-use consumption vis-à-vis the stock of baseline and efficient equipment across various building types, which are inputs into the technical and economic potential analyses. But it is used also to gather program-related inputs to various models. Absent sufficient funding for primary data collection or the availability of data, analysts must rely on other sources. These include program experience in other similar jurisdictions or the U.S. Department of Energy's Energy Information Administration, which publishes building-level data predominantly at the regional and national level. Authors should explicitly mention if non-state-specific data are being used as a proxy for state- or utility-level data.

DATA AVAILABILITY

Quantitative data, particularly data acquired through primary research within the relevant jurisdiction, are often very costly to procure. Data that feed into models of customer participation, for example, can be gathered through customer surveys, which are toilsome and can be misrepresentative in and of themselves. Historical data and data from other, similar jurisdictions can also be used as proxies. Data on energy-efficient equipment and measures are seemingly boundless, but savings and costs values for similar measures usually differ across jurisdictions and climate zones, as well as temporally. Data collection and reporting are always an issue, either relative to a potential study's budget or the degree of transparency.

Utilities are protective of data they consider to be competitively sensitive, as well as of their customers' data and privacy. Utilities still need to provide these data to analysts, although interviewees noted that sensitive data are often given to analysts with little explanation of the underlying assumptions (e.g., utility sales forecasts and avoided costs). If the data are reported in a study, they are usually redacted in the publicly available version. For example, avoided-costs assumptions are extremely revealing in ascertaining the robustness of savings potential results, particularly in how NEBs are treated. Only a third of the studies reviewed for our report provided data on avoided costs—usually in the appendixes—and none of these provided any information on how they were calculated or the types of avoided costs included.

Furthermore, given their competitively sensitive data, potential studies are not always publicly available. While our sample of 45 studies is quite robust, our discussion likely would have benefitted from the inclusion of additional studies.

Cost-Effectiveness and Benefit-Cost Analyses

Utility regulators and other policymakers typically require that energy efficiency programs and other demand-side investments are shown to be cost effective before they are approved. This policy requirement naturally extends to the realm of the potential study. Well-developed potential studies should be certain to evaluate cost effectiveness consistent with regulatory policy and be transparent about the types of tests used in determining cost effectiveness. The majority of studies we reviewed use the TRC test as the primary evaluation for cost effectiveness at both the measure and program level, although many studies include other cost-effectiveness tests to provide additional perspective. These tests include the Participant Cost Test (PCT), the RIM test, the Program Administrator Cost (PAC) test (also referred to as the Utility Cost Test, or UCT), and the SCT.[18]

In a potential study, cost effectiveness is generally estimated at two points. The first is within the economic potential analysis, at the measure level. This is usually accomplished via the TRC test, to determine which energy efficiency measures should be included in the achievable potential analysis. In other words, the cost effectiveness of a measure is screened by comparing a customer's costs with a utility's avoided cost of supply. If the levelized cost of saved energy of a measure is less than a utility's avoided cost of supply, then it makes economic sense for a utility to purchase that marginal unit of energy efficiency instead of the relatively more expensive supply alternative.[19] It is important to note that when the TRC test is applied at the measure level, it usually does not include program administrative costs, since these are difficult to disaggregate at the measure level. The assumptions behind a utility's avoided costs therefore have major implications for the types of measures that pass cost-effectiveness screening in the economic potential analysis and, ultimately, the quantity of achievable savings potential estimated in the study. Data on avoided costs are infrequently reported, however, both in terms of the values and the methodologies. Publicly available data on measure costs and savings, on the other hand, are much more pervasive and transparent.

The second point at which cost effectiveness is measured is at the program or portfolio level, utilizing savings and costs results from the achievable potential analysis. Regulatory authorities are generally more interested in the cost effectiveness of an overall program or portfolio of programs than in measure-level cost effectiveness.[20] So it is critical that cost-effectiveness tests are applied correctly. A recent Synapse Energy Economics study, *Best Practices in Energy Efficiency Program Screening*, discusses the best-practice application of the various cost tests within the context of state regulatory authorities. The study notes that analysts must "ensure that each test is being applied in a way that achieves its underlying objectives, is internally consistent, accounts for the full value of energy efficiency resources, and uses appropriate planning methodologies and assumptions" (Woolf et al. 2012). The study also notes that there is a great deal of variation in how these tests are applied across

[18] There is growing interest in using the PAC test as the primary test for cost effectiveness as it measures the costs and benefits of energy efficiency program investments from the utility or program administrator perspective only (see table 1). The TRC, on the other hand, accounts for customer costs but often does not include any customer benefits, while all utility costs and benefits are included. Neglecting customer benefits but including customer costs means that the TRC test underestimates cost-effective potential.

[19] The levelized cost of saved energy is the average cost per kilowatt-hour of savings generated over the life of a measure. Energy planners commonly use levelized cost as a way to express the cost of long-term energy supply investments. For electricity generation technologies, for example, the levelized cost represents the per-kilowatt-hour cost expressed in real dollars of building and operating a power plant over an assumed financial life, duty cycle, and capacity factor.

[20] Some states require individual measures to be cost effective in order for them to be included in actual utility rebate programs. We could not discern from our review of the 45 studies which states have this requirement. But from discussions with interviewees, we understand that, generally, program and portfolio cost effectiveness is of paramount concern to regulators.

states. But where this is most glaring is in the fact that most states fail to account for the full value of energy efficiency resources when evaluating the cost effectiveness of programs. Our review of the 45 potential studies revealed the same trend for potential studies. All but a handful of studies fail to account for the full value of energy efficiency—an issue that we discuss in greater detail below.

Program cost effectiveness is evaluated in the achievable potential analysis. This is because achievable potential scenarios are intended to reflect actual program and portfolio potential by taking into account market and other barriers to energy efficiency adoption.[21] However, program cost effectiveness in the achievable potential analysis is not defined by levelized measure costs as it is in the economic potential analysis. Rather, the focus is on the overall benefits and costs, such as to the utility, customer, or both, since achievable potential is intended to represent utility-territory or statewide potential.[22] The TRC test is, again, the primary test used to evaluate program cost effectiveness in potential studies. However the PAC test and PCT are also regularly included, and the RIM and PCT to a lesser degree. When the TRC test is applied at the program or portfolio level, program administrative costs are included. These costs are not included when the TRC test is applied at the measure level within the economic potential analysis. We expound on the various cost-effectiveness tests below.

UNDERSTANDING THE VARIOUS BENEFIT-COST TESTS AND WHAT THEY CONVEY ABOUT POTENTIAL

Potential studies generally estimate the cost effectiveness of individual measures and overall achievable potential estimates using the TRC test. A state's regulatory commission commonly mandates this test as the primary method of cost-effectiveness evaluation for energy efficiency. Because each test examines a different set of benefits and costs, it is not uncommon for a study to run additional cost-effectiveness tests beyond the TRC; each test provides a unique perspective on the potential impacts of energy efficiency investments on the various market actors. Table 1 summarizes the various tests and the types of costs and benefits included in each calculation.

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[21] It is important to remember, though, that in the case of studies that examine multiple scenarios in the achievable potential analysis, there is usually a scenario where customer incentives are set at maximum levels, or 100% of a measure's incremental costs. This is not typical for most programs.

[22] While some potential studies will go a step further to estimate realistic or program potential, which account for programmatic barriers, none of the studies we reviewed estimated cost effectiveness for these scenarios.

Table 1. Summary of key benefits and costs included in various tests

	Participant test	RIM test	TRC test	SCT	PAC test
Benefits[1]					
Primary fuel(s) avoided supply costs		✓	✓	✓	✓
Secondary fuel(s) avoided supply costs			✓	✓	
Primary fuel(s) bill savings (retail prices)	✓				
Secondary fuel(s) bill savings (retail prices)	✓				
Other resource savings (e.g., water)	✓		✓	✓	
Environmental benefits[2]				✓	
Other NEBs			rarely[3]	in theory only	
Costs[4]					
Program administration[5]		✓	✓	✓	✓
Measure costs					
Program financial incentives		✓	✓	✓	✓
Customer contributions	✓		✓	✓	
Utility lost revenues		✓			

[1] We use the term "primary fuel(s)" to represent the fuels provided by the utility running the efficiency program; the term "secondary fuel(s)" refers to fuels not provided by the utility. For example, for an efficiency program run by an electric-only utility, electricity savings are primary fuel savings and gas or fuel oil savings are secondary fuel savings. [2] Environmental benefits include avoided environment compliance costs, which many states incorporate into their estimates of avoided costs (Woolf et al. 2013). [3] Although not officially part of the California Standard Practice Manual definition, the original discussions underlying the TRC and the conceptual rationale for adding the participant's out-of-pocket costs to the utility's program costs are supportive of incorporating participant NEBs into the calculation. At various times, a number of states have attempted to measure and include these types of benefits, but the near-universal practice these days is to ignore them in the calculation of the TRC. [4] Just as savings of secondary fuels and other resources are benefits captured by different tests, any increases in secondary fuel costs or other resource use would be captured as either increased costs or negative benefits. Such increases would be estimated using avoided costs or retail prices in the same way as the benefits from reductions in use of such resources would be estimated for the different tests. [5] We use the term "administration" here to include all program costs other than financial incentives for efficiency measures. This includes program management, administration, marketing, training, evaluation, and so on. *Source:* Neme and Kushler 2010.

The costs and benefits included in the Participant Cost, RIM, and PAC tests are fairly straightforward. However there is considerable room for interpretation of benefits and costs when using the TRC test and SCT (NHPC 2014). These tests are constructed to determine the impact of energy efficiency investments on all parties within the defined geographic area. The tests, then, should account for all the various energy and NEBs and costs that energy efficiency investments create, even if they are hard to quantify. If there is consensus that the NEBs are greater than zero, then a conservative adder can be incorporated to the benefits and costs to account for that. Many states and regions, such as Vermont and the NPCC, incorporate environmental adders or credits (cost reductions) into their potential studies to account for the various NEBs of energy efficiency as well as non-energy costs (Woolf et al. 2013).

Few studies include all NEBs and costs, so these two tests infrequently convey the total net benefits or costs of energy efficiency measures and programs. The TRC test, for example, includes customer technology costs on one side of the equation. But on the other side, it only includes direct energy savings, despite the fact that customers invest in (i.e., benefit from) energy efficiency for many other reasons. Still, methodologies for estimating by how much and in which direction NEBs are achieved are still evolving. But considering the wide array of additional benefits and costs not captured by these tests—particularly benefits such as avoided emissions, reduced customer arrearages, and improved customer comfort—the difference is not insignificant.

Whether or not a study includes NEBs and costs, analysts should strive to be clear and transparent about their assumptions and justifications for including or ignoring them. The decision is typically based on existing state regulatory policies or the request of the client. The Vermont Department of Public Service (DPS), for example, requires use of the SCT, which includes these NEBs and costs. But documentation on the assumptions and calculations is difficult to find as resources are buried in various DPS dockets going back more than a decade. A report published by Synapse Energy Economics, Inc., titled *Energy Efficiency Cost-Effectiveness Screening in the Northeast and Mid-Atlantic States* (Woolf et al. 2013), provides a detailed survey of cost-effectiveness screening issues and practices in these states that other states can use to develop their own guidelines.

AVOIDED COSTS

The cost effectiveness of energy efficiency measures or programs is determined vis-à-vis a utility's avoided cost of supply. The exception is the PCT, which quantifies benefits based on customer bill savings. A utility's avoided cost is the additional cost of producing one marginal unit of energy ($/kWh). This typically consists of fuel costs and the corresponding portion of a power plant's operation and maintenance (O&M) costs. In most cases it also includes avoided capacity (new generation assets), although this is discounted and there is a tendency to be conservative in its estimate. To a much lesser degree, it includes avoided transmission and distribution (T&D) costs. The great majority of studies we reviewed define avoided costs relative to avoided energy and capacity costs. Only 11 of the 45 studies include avoided T&D costs. Quantitative data on utility avoided costs are usually considered proprietary and are infrequently disclosed in the 45 studies we reviewed.

The NPCC has noted that "non-fuel variable costs are generally a minor element of production costs." In other words, fuel costs are a major factor in determining a utility's avoided costs of production and therefore are the primary factor in determining whether or not to invest in energy efficiency (NPCC 2010). It is important to understand that utility avoided costs are considered a benefit and are treated as such in the various cost-effectiveness tests (see table 1). However many other benefits accrue to a utility from forgoing electricity production besides avoided fuel costs (and O&M), such as the potential costs of future carbon allowances and avoided water costs.

Furthermore, energy efficiency measures deliver benefits beyond the economic savings captured in levelized cost calculations, including improved comfort, health, and productivity, although these are difficult to quantify precisely. The Northwest Power Act, for example, directs NPCC and Bonneville Power Authority to give a 10% cost advantage to energy efficiency measures over other resources.[23] The Vermont Public Service Board also requires a benefits adder to energy efficiency resources.[24] Massachusetts includes a number of NEBs in its cost-effectiveness calculations, such as the cost to utilities of purchasing greenhouse gas allowances. It also includes various participant NEBs such as comfort, health and safety, and impacts on property values (Woolf et al. 2013). It is clear that the additional NEBs of energy efficiency are greater than zero and should be treated as such, but this level of analysis is rare.

Based on our research and discussions with interviewees, we discovered that the great majority of potential studies do not include these additional avoided costs and NEBs in cost-effectiveness screening, either at the measure or program/portfolio level. In fact, a large majority of studies fail to report avoided-cost assumptions at all, let alone the components of those avoided costs. Utilities often consider their avoided costs to be proprietary, so transparency is a major issue. Interviewees responded that it is rare for utilities to disclose information about their avoided-cost calculations for a potential study. Standard practice is to provide avoided costs without any additional information. Some states, such as California, New Jersey, and the New England region, periodically commission independent studies of avoided costs which are made publicly available.

Due to the complexity of the subject and the lack of transparency, it is often difficult to understand the components of a utility's avoided-cost calculations. But it is safe to say that the great majority of potential studies are excluding at least some marginal energy efficiency measures because they do not take into account all avoided costs. It is difficult to quantify the impact on overall potential of excluding these additional benefits, however. One could review the cost-effectiveness results for individual measures in the economic potential analysis to determine which measures are languishing on the margin—just below a benefit-cost ratio of 1—to get some sense of the magnitude. However this is extremely time consuming. Comparing avoided costs across studies is not helpful either, as factors affecting avoided costs vary considerably by utility, state, and region.

Overlooked Measures, Market Segments, and Sectors

Many studies overlook certain measures (other than emerging technologies), market segments, and sectors. For example, one study we reviewed does not include savings opportunities for the industrial sector. This limits overall savings potential considerably, particularly because the study covers a 20-year time period. Other overlooked opportunities are found in certain electrical devices, early replacement of measures, and the manufactured housing market. The agricultural sector is also often overlooked: only a handful of studies we reviewed include savings opportunities in this sector. Of course, farmers and other rural customers commonly purchase their electricity from cooperatives as opposed to investor-owned utilities, so the agricultural sector is typically analyzed only in statewide studies.

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[23] https://www.nwcouncil.org/reports/poweract/

[24] Final Order in Vermont Public Service Board Docket No. 5270: http://psb.vermont.gov/sites/psb/files/projects/EEU/screening/5270final.pdf

To give some perspective on this issue, in 2009 the Electric Power Research Institute (EPRI) and McKinsey & Company published two nationwide energy efficiency potential studies (EPRI 2009; Granade et al. 2009). The studies produced greatly different results over the same study time period: through 2020, EPRI estimated economic potential savings that were 43% lower than McKinsey's estimates. At a high level, the two studies approached potential estimates from different perspectives: EPRI focused on the savings potential given existing programs and best practices while McKinsey focused on exploring ways to significantly change the status quo.

A number of entities, including ACEEE and McKinsey, cited the differences in the methodologies and assumptions of the two studies to explain the contrasting results. We have discussed some of the reasons above, such as the treatment of emerging technologies. In addition, the McKinsey study included additional end uses of energy (e.g., street lighting, additional industrial processes, additional residential and commercial electronic devices and appliances) that accounted for 80% of the difference in potential estimates. The McKinsey study also allowed for early replacement of measures prior to end of life. On the other hand, the EPRI study did not account for savings from codes and standards, and assumed a relatively flat electricity price forecast.

Review of Quantitative Results

Table 2 shows some of the overall quantitative results for the 45 studies we reviewed. Readers should note that assumptions and methodologies of potential studies can vary significantly across studies even when accounting for geographic, demographic, and economic differences, rendering direct comparisons of one study to another problematic. Table 3 organizes the studies into three bins based on the time period of the analysis: 1–9 years, 10–15 years, and 16–21 years. Our intent in creating these bins is to assess if there is any high-level correlation between the study period and average annual percentage of savings.

In table 2 and figures 2, 3, and 4 below, we present maximum achievable potential savings. Additional results can be found in tables B2, B2, and B3 in Appendix B. We have chosen to focus on maximum achievable potential results rather than results from other scenarios because they are intended to represent the maximum amount of cost-effective energy efficiency that can be captured. These maximum values are predicated on concerted marketing and education efforts by program administrators in addition to generous customer financial incentives, generally on the order of 100% of the incremental costs of an energy-efficient piece of equipment or measure. Each study that reported cost effectiveness at the program portfolio level found the associated expenditures to be cost effective from a TRC test perspective. To allow for high-level comparisons across studies, which have varying time periods, we normalize the reported cumulative savings potential results by calculating average annual savings.

Table 2. Overall quantitative results

Year of publication	Author	Jurisdiction (state, utility, or region)	Electric /gas	Analysis period (years)	Maximum achievable results (%)			
					Electric		Natural gas	
					Cumulative	Avg. annual	Cumulative	Avg. annual
Studies with analysis period of 16–20+ years								
2013	Georgia Tech	Eastern United States	Electric	21	31.5%	1.5%		
2013	EnerNoc	Idaho Power	Electric	21	12.2%	0.6%		
2013	Navigant	Kansas City P&L	Electric	20	29.2%	1.5%		
2013	Cadmus/EHI	LG&E/KU (KY)	Both	20	6.1%	0.3%	9.0%	0.5%
2013	Cadmus	Puget Sound	Both	20	16.0%	0.8%	21.0%	1.1%
2013	Cadmus	PacifiCorp	Electric	20	12.0%	0.6%		
2013	EnerNoc	Avista (WA & ID)	Electric	20	17.6%	0.9%		
2013	ACEEE	Louisiana	Both	17	16.0%	0.9%	12.0%	0.7%
2012	ICF International	Entergy NO	Electric	20	17.2%	0.9%		
2012	ACEEE	Kentucky	Both	18	19.1%	1.1%	24.5%	1.4%
2011	AEP Ohio (Navigant)	AEP Ohio	Electric	20	22.0%	1.1%		
2011	GDS/Cadmus	Vermont	Electric	20	25.4%	1.3%		
2011	Cadmus	PacifiCorp	Electric	20	16.0%	0.8%		
2011	Global Energy Partners	TN Valley Auth.	Electric	20	19.8%	1.0%		
2011	Global Energy Partners	New Mexico	Electric	16	11.1%	0.7%		
2011	ACEEE	Arkansas	Both	16	22.0%	1.4%	16%	1.0%
2010	ACEEE	North Carolina	Electric	16	32.0%	2.0%		
2009	PA Consulting	NPC/SPPC (NV)	Electric	20	15.6%	0.8%		
2009	ACEEE	Pennsylvania	Both	18	22.7%	1.3%		0.8%
2009	ACEEE	Ohio	Electric	18	23.4%	1.3%		
2009	ACEEE	South Carolina	Electric	16	27.6%	1.7%		

Year of publication	Author	Jurisdiction (state, utility, or region)	Electric /gas	Analysis period (years)	Maximum achievable results (%)			
					Electric		Natural gas	
					Cumulative	Avg. annual	Cumulative	Avg. annual
Studies with analysis period of 10–15 years								
2014	Navigant	CenterPoint (MN)*	Gas	11				2.2%
2013	GDS	Washington, DC	Both	10	29.4%	2.9%	24.1%	2.4%
2013	GDS	Michigan	Both	10	15.0%	1.5%	13.4%	1.3%
2013	Navigant	California*	Both	12		1.0%		
2013	EnerNoc	Ameren (MO)	Electric	15	15.9%	1.1%		
2013	ACEEE	Mississippi	Both	10	12.8%	1.3%	9.8%	1.0%
2012	Nexant/Cadmus	Georgia Power	Electric	10	15.3%	1.3%		
2012	Cadmus	Iowa Util. Assoc.	Both	10	17.3%	1.7%	15.6%	1.6%
2012	Black and Veatch	FirstEnergy (OH)	Electric	13	16.8%	1.3%		
2012	SWEEP	Southwest	Electric	11	21.0%	1.9%		
2012	GDS/Nexant	Pennsylvania	Electric	10	17.3%	1.7%		
2011	ACEEE	Missouri	Both	15	17.3%	1.2%	13.0%	0.9%
2010	KEMA	Xcel Colorado	Both	11	17.5%	1.6%		
2009	Energy Center of WI	Wisconsin	Both	10	16.0%	1.6%	11.0%	1.1%
2009	Navigant	Minnesota*	Gas	11				1.8%
Studies with analysis period of 1–9 years								
2013	Energy Center of WI	North Shore Gas (IL)	Gas	3			2.4%	0.8%
2013	Energy Center of WI	Peoples' Gas L&C (IL)	Gas	3			1.5%	0.5%
2013	ICF International	ComEd (IL)	Electric	6	10.0%	1.7%		
2013	KEMA	Xcel (CO)	Electric	8	12.1%	1.5%		
2012	EnerNoc	Indiana P&L	Electric	4	5.2%	1.3%		
2012	EnerNoc	New Jersey	Both	4	5.9%	1.5%	1.8%	0.5%
2010	Global Energy Partners	ConEd (NY)	Both	9	9.0%	1.0%	6.0%	0.7%

Year of publication	Author	Jurisdiction (state, utility, or region)	Electric /gas	Analysis period (years)	Maximum achievable results (%)			
					Electric		Natural gas	
					Cumulative	Avg. annual	Cumulative	Avg. annual
2009	Forefront Economics/Gil Peach	Duke Ohio	Both	5	3.1%	0.6%	0.7%	0.1%
2009	Forefront Economics/Gil Peach	Duke Kentucky	Both	5	3.4%	0.7%	1.0%	0.2%

*Navigant did not report cumulative savings potential, which we use to estimate average annual savings potential. Navigant instead reported annual values for benchmark years: this value represents maximum annual achievable potential in 2025. Cumulative savings percent values are included in the model but not listed in the final report, as CenterPoint is focused on annual targets. For its California study, cumulative savings values are included in the final report but at the sector level, not aggregated statewide. For its Minnesota study, Navigant estimated potential for three utilities; this value represents the median, with a range of 1.4%–2.0%.

For electricity, average annual savings range from 0.3% to 2.9% with a median of 1.3%. Removing the two outliers, the studies found average annual savings between 0.5% and 2.1%. For natural gas, average annual savings range from 0.1% to 2.4% with a median of 0.9%. Disregarding the four outliers (see figure 2), the majority of studies found average annual savings between 0.5% and 1.8%.

As figure 2 shows for electricity, it appears that studies with a longer time horizon have lower average annual potential. But the correlation is weak: we estimate an r-squared of 0.13. This could be due in part to the fact that existing technologies can be heavily adopted over the first decade, while the new technologies and practices that would emerge during the second decade are not included in most potential studies. As new energy-savings technologies and practices are developed, they will increase potential savings in the out years. Models of customer participation also break down as the study period grows: projecting market dynamics and subsequent customer behavior over time is an inaccurate exercise. As a result, analysts usually err on the side of conservatism when modeling participation beyond three to five years in the future, which can limit overall potential.

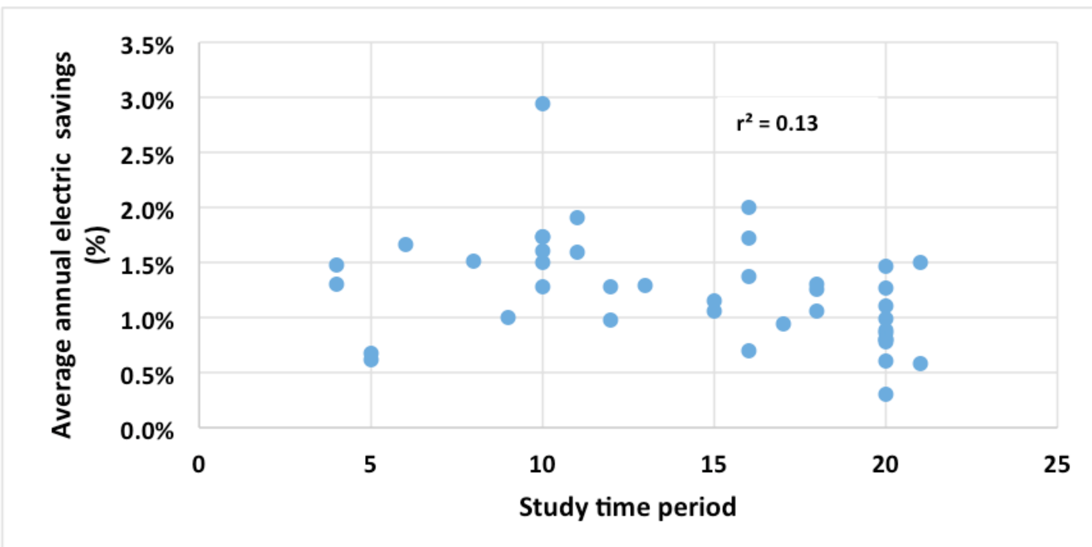

Figure 2. Average annual electric savings (%) and study time period, 1–20 years

Figure 3 presents results for the natural gas studies. The correlation between study time period and average annual potential is weak for natural gas studies as well, although our sample size is considerably smaller: we estimate an r-squared of just 0.03. Overall, the average annual maximum achievable potential savings, as a percentage of sales, are slightly lower for natural gas than for electricity. This is consistent with past meta-analyses and natural gas program portfolio performance generally. However average annual maximum achievable savings potential for natural gas remains just as high as electric potential in some jurisdictions. For example, a recent Navigant study conducted for CenterPoint Energy Minnesota found annual energy savings of at least 1.5% through 2025 across five scenarios that assumed various levels of program design efforts and incentive levels. While Minnesota has a considerable heating load, it is clear that many natural gas utilities are still finding abundant energy efficiency resources in their territories.

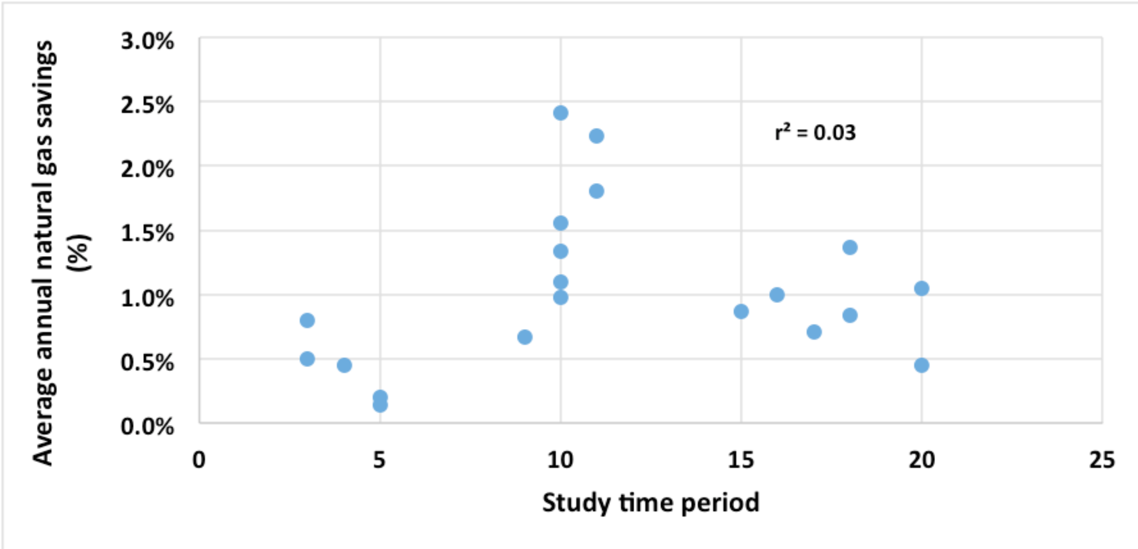

Figure 3. Average annual natural gas savings (%) and study time period, 1–20 years

There also does not appear to be a correlation between geography and energy efficiency potential. Our sample of studies covers all regions of the country and, at a high level, there appears to be no noticeable variation in potential findings across regions. Figure 4 is the same graphic as figure 2, only the data are formatted to distinguish results across the four census regions. Figure 4 shows that each region has found varying levels of potential savings within a similar time frame. It also shows that some states and utilities within each region can achieve significant levels of potential savings, on the order of 1.5% average annual savings or higher.

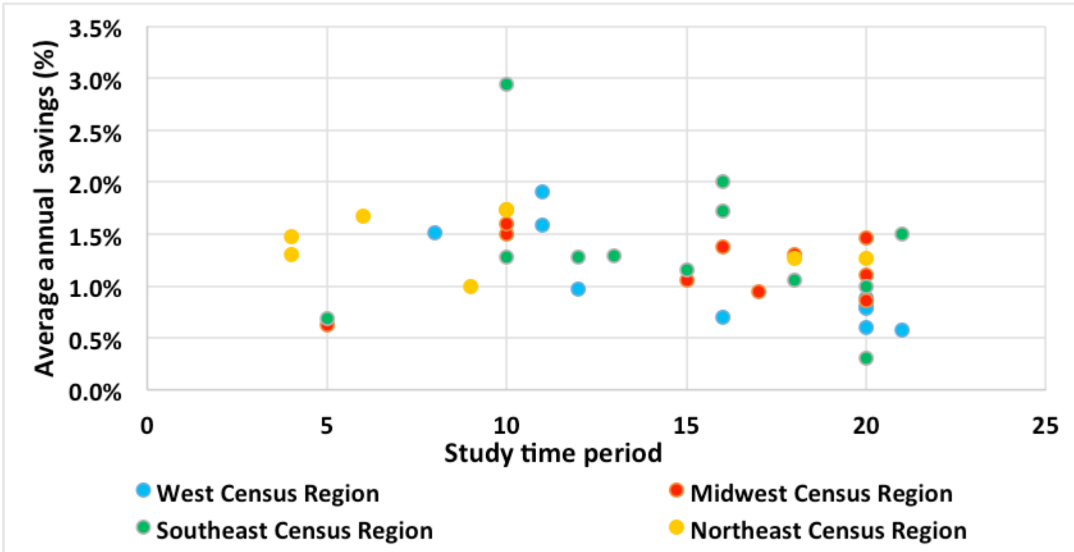

Figure 4. Average annual electricity savings (%), by census region

THE RELATIONSHIP BETWEEN SAVINGS POTENTIAL AND PARTICIPATION AND AVOIDED COSTS ASSUMPTIONS

Below we delve into the quantitative results in a bit more detail so we can examine the relationship between savings potential and several key potential study assumptions—in particular participation rates and utility avoided costs. Our intent was to examine the relationship of participation, avoided costs, and emerging technologies relative to savings potential within a study. But only one of the 45 studies reported quantitative data for all three variables: the 2011 GDS/Cadmus study for Vermont (GDS 2011). Only three studies reported both avoided costs and participation data. Apart from the Vermont study, none of the studies that clearly defined their emerging technology assumptions reported quantitative data for either avoided costs or participation. In general, as we noted earlier, data on emerging technologies are sparse. This is in part because of the short-term focus of many of the studies, but mostly because many studies are unclear about which measures are considered emerging.

Figure 5 below shows that higher participation rates generally lead to higher savings potential, which is to be expected. The statistical correlation is moderate, however, with an r-squared equal to 0.536, in part because of the limited sample size (n=10). Still, our review of these studies and comments from interviewees suggest that participation is a primary factor in estimating overall savings potential.

The participation rates we include in figure 5 are averages. For the purposes of estimating achievable savings potential, participation rates are generally assigned to individual measures and differ across sectors. But they can also be assigned to end uses or programs. In order to estimate a single representative participation rate for a study, we first averaged the assumed maximum participation rates (i.e., the highest participation rate achieved over the analysis period for a measure, end use, or program) across all measures within a sector and by equipment type, if specified (either equipment, such as refrigerators, or non-equipment, such as insulation). We then took the average of all measures within a sector and across equipment types and averaged those rates across sectors. In other words, the rates in figure 5 do not differentiate between residential and nonresidential measures or equipment type.

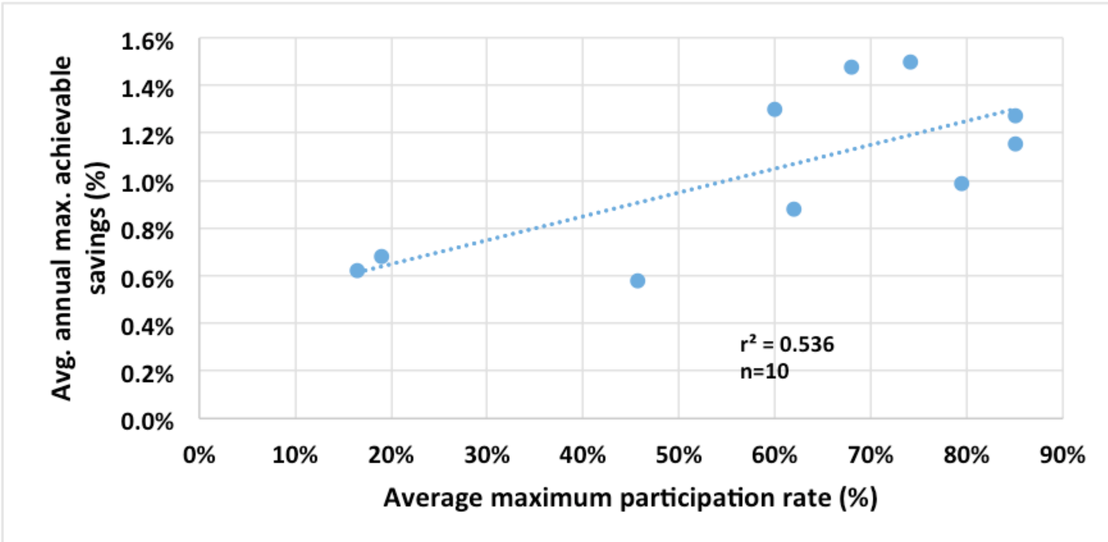

Figure 5. Average annual maximum achievable savings (%) and average maximum participation rate (%)

It is worth noting, however, that there is not a lot of variation in maximum participation rate assumptions reported in these studies. For a specific measure or program, certainly, participation will vary considerably over time. But often the analytical concern is the maximum participation rate and the year in which that rate is achieved. For example, one study assumes only two maximum participation rates—65% and 85%—across dozens of residential equipment and non-equipment measures. There is generally more variation of assumed participation rates for nonresidential measures, but even then the variation can be limited. The same study assumes only three maximum participation rates—50%, 59%, and 77%—across dozens of commercial equipment and non-equipment measures. Another study by a different author reports a range of participation rates across nonresidential equipment types in its maximum achievable scenario that is limited to 69%–80%.

In figure 6 below, we show that utility avoided costs and average annual savings potential are also positively correlated. The statistical correlation is modest, as the sample size for avoided costs is even smaller: we estimate an r-squared of 0.27. However, it is known that higher utility avoided costs increase the potential for individual measures to pass cost-effectiveness tests. So it is expected that higher avoided costs lead to greater savings potential. Unfortunately, as we discussed above, most studies do not report data on avoided cost assumptions. This makes it difficult for readers to ascertain if estimated savings potential is representative of actual savings potential.

The data points in figure 6 are for avoided-cost assumptions in the year 2025 and average annual savings for studies with an analysis period that goes through at least 2025. Only six studies with analysis periods of this length report avoided costs. A handful of other studies report avoided costs, but the analysis periods are shorter.

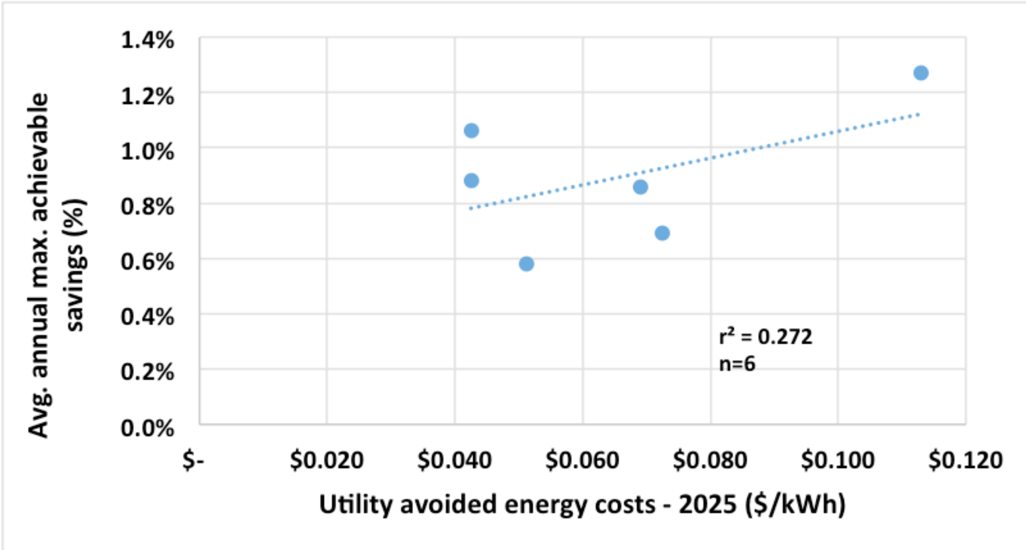

Figure 6. Average annual maximum achievable savings (%) and utility avoided energy costs ($/kWh) in 2025

While these analyses suffer from very small sample sizes, the data we were able to collect provide some insight into the relationship between these variables and savings potential. The theory behind these relationships is not surprising: analysts model savings potential primarily as a function of economics, from the perspective of the customer or the utility. But these charts give some idea of the magnitude of the impact of these variables on savings potential. Additionally, more robust estimates of utility avoided costs tend to drive savings potential upward. In figure 6, the highest avoided-cost estimate includes NEBs such as avoided carbon and other externalities, as well as avoided T&D costs. Another of the higher estimates includes avoided T&D costs but does not include NEBs. The remaining avoided costs estimates, however, consider only avoided energy and capacity costs.

Where the data above belie these possible relationships, data on other variables would help readers understand their relative importance. Since no study reported quantitative data for all three of the primary variables, we are unable to determine why, in figure 6, for example, relatively high average annual savings are achieved despite relatively low avoided-cost assumptions. Unfortunately, transparency is not a priority in many energy efficiency potential studies, so readers should question the veracity of results when studies fail to provide detailed information about all of their assumptions. Faced with questionable results and the dearth of consistent data, stakeholders should demand greater transparency, at least for the sake of further research on these relationships.

Best Practices in Potential Study Design

One of our goals of this report is to inform readers about the elements that make up a potential study and how various assumptions about those elements and the methodologies of the analyses can have a significant impact on savings potential. It is clear that studies are only as informative as their anatomy allows. Approaches can vary depending on the goals of the study—and also on the budget, although several interviewees noted that larger budgets do not necessarily lead to greater accuracy. Overall, as we have seen in this report, certain approaches can lead to more credible results. Here we discuss at a high level the elements that constitute best practices, based on the qualitative and quantitative results gleaned through our research. Our hope is that studies will strive for these levels of rigor and transparency in the future.

POTENTIAL STUDY SCOPES AND OBJECTIVES

Earlier in this report we referenced the EPA graphic on the potential study continuum (see figure 1), which conveyed the objectives for different types of potential studies relative to the amount of detail required and the cost and length of time for completion. Best practices must be discussed relative to the goals of a particular potential study. This is because the assumptions and methodologies for one type of study are not necessarily relevant to another. For example, studies that build the policy case for energy efficiency should generally use a different methodology than studies used for detailed program or long-term energy system planning.

The great majority of studies we reviewed were conducted with a medium- to long-term focus (greater than ten years) with the apparent intent of assessing the costs and savings of energy efficiency resources. This was usually for the purposes of identifying available energy efficiency measures across all customer classes for general long-term planning, informing the IRP process, or simply in response to a regulatory requirement. The identification of available energy efficiency measures is presumably used to inform program development to some degree, but most of these studies were not explicit about their application to the program planning process. As one study noted, "the long-run planning nature of the Potential Study means that results should not be applied directly to short-term DSM planning activities, including, but not limited to, program implementation plans or utility goal setting" (ICF 2012). This statement appears to be representative of our sample of 45 studies. Long-term studies evaluated energy efficiency predominantly for IRP or general long-term planning purposes. Studies that limited the time period to ten years or less were most likely to evaluate potential to inform the program planning or target setting process.

For a number of reasons, energy efficiency potential studies are best suited to guide short-term program development and deployment—originally their intended use. They can also be informative when incorporated into the IRP process and when used to develop utility savings targets. Well-designed potential studies that leverage primary research as well as historical program experience can provide a snapshot of existing market conditions. They can also help identify effective program design elements that can lead to sustained, successful energy efficiency programs. Utilities are generally concerned with the short term (three to five years), and economic models work best when assessing short-term changes in market and customer behavior.

In the long term, the availability of energy efficiency resources can have major implications on investment in and the deployment of generation resources, so a thorough quantification of energy efficiency is essential. However, the uncertainty of economic models increases considerably as the study period grows longer. Many of the medium- to long-term studies we reviewed were conducted for IRP or general long-term planning purposes, but few discussed the inherent uncertainty of economic modeling and forecasting. This is not necessarily a criticism of these studies. Rather, it raises the question of how energy efficiency is incorporated into long-term system planning decisions informed by the IRP process.

Accounting for the Full Benefits of Energy Efficiency

The majority of energy efficiency potential studies we reviewed did not try to incorporate all benefits of energy efficiency into their analyses of cost effectiveness, either at the measure or portfolio level. It is true that some NEBs may be considered risky to quantify or may not create value depending on the objectives of the potential study. Regardless, as we mentioned previously, there is a good deal of research on the NEBs of energy efficiency. While these benefits may be hard to quantify, there is little doubt that their overall effect is greater than zero. RAP's *Ten Pitfalls of Potential Studies* covers this topic concisely and with helpful detail. The Synapse Energy Economics study, *Best Practices in Energy Efficiency Program Screening*, covers it extensively and in great detail (Woolf et al. 2012).

Whether in evaluating measure cost effectiveness or developing estimates of utility avoided costs, excluding NEBs means leaving out measures on the margin that could have significant implications for overall potential. Although quantifying NEBs is difficult, analysts have addressed this difficulty by incorporating "adders," usually in terms of a percentage, though occasionally in terms of $/kWh, which are aggregated with other types of avoided costs. California, Iowa, Minnesota, Vermont, and the NPCC, for example, incorporate environmental adders or credits (cost reductions) to account for various NEBs of energy efficiency as well as non-energy costs such as reduced customer comfort levels. Vermont assumes a 10% reduction in costs to account for "the risk diversification benefits of energy efficiency measures and programs," and Vermont's SCT includes an environmental adder of $0.007/kWh saved (GDS 2011).

Transparency, Transparency, Transparency

A number of the studies we reviewed were not fully transparent regarding their methodologies and assumptions. This is unsurprising and not necessarily their fault, given the proprietary and competitively sensitive nature of many of their elements. However this lack of information is particularly confounding when it comes to the more influential elements of a study, for example, the assumptions behind maximum achievable and program and realistic potential scenarios, customer participation models, avoided costs, and emerging technologies.

Potential study scenario definitions were particularly opaque when it came to assumptions about market and program barriers to customer participation in energy efficiency. Like NEBs, these types of factors are difficult to quantify. But analysts understand them to be greater than zero, so they must be included somehow if analyses are truly to reflect existing and forecasted market conditions. As our interviews with study authors revealed, the impact of market and program barriers on customer participation is generally left to the judgment of the analyst. Navigant's study for CenterPoint Energy in Minnesota is the most transparent of any of the studies we reviewed in this respect. It provides information on how customer participation and non-incentive costs are assumed to change as a result of enhanced program design intended to address these barriers (Navigant 2013b).

Our research also shows that modeling customer participation over time can be costly and does not produce particularly accurate results. Models of customer participation are one of the most influential elements in an energy efficiency potential study. For this reason, readers should be given as much information as possible on how these models are constructed in order to understand how changes in customer behavior can lead to changes in energy efficiency potential estimates. Few studies provide any information on the assumptions or methodologies of their customer participation models, e.g., calculations for customer payback or the derivation of customer acceptance curves. It is also uncommon for studies to publish quantitative data on their assumptions about participation rates. Yet in figure 5 above, we show the positive, albeit weak, correlation between participation rates and savings potential. Greater transparency about participation rate assumptions and calculation methodologies will enhance stakeholders' ability to evaluate the accuracy of the results. If studies consistently lowball participation, this will have a significant impact on overall savings potential.

Most utilities consider their avoided costs to be competitively sensitive, although 15 studies—one-third of the sample—published these data either in the report itself or in a supplemental document. Since utility avoided costs are the benchmark for energy efficiency cost effectiveness, studies that provide their underlying values and assumptions will help readers assess the veracity of overall potential results. If quantitative data are not offered, then studies should try to be transparent about the qualitative factors that utility avoided costs represent beyond variable fuel costs and O&M, for example, avoided capacity and T&D costs. It is understood that higher utility avoided costs lead to greater opportunities for cost-effective energy efficiency savings, which we show in figure 6 above. But scant data make it difficult to examine the magnitude of this relationship thoroughly.

Assumptions about emerging technologies (ETs) can also have a noticeable impact on potential results, particularly for those studies that consider long-term savings potential (i.e., ten years out or more). It is difficult to assess the prevalence and impact of emerging technologies in the 45 studies we reviewed, because most of them are ambiguous about the measures they consider emerging. If the goals of a potential study include long-term planning and ascertaining the maximum energy efficiency resources available, then it would be prudent to include at least some ETs. Most importantly, the study should be transparent about its assumptions, such as the timing of measures' commercial availability, savings, costs, and so forth.

Authors and analysts should also be explicit about how codes and standards are treated and their quantitative impacts. The perennial debate about codes and standards and their purported erosion of savings potential suffers from limited research on the topic. However, the research that exists has shown that new technologies (e.g., LEDs) and program delivery strategies (e.g., behavioral programs) can more than offset the loss of savings potential from codes and standards, at least in the near term (Geller et al. 2014).

Potential studies provide unique opportunities for states and utilities to strengthen their understanding of the quantitative relationship between codes and standards and savings potential. However the vast majority of the studies we reviewed provide little discussion of this issue or data that could elucidate it. ACEEE research on building energy codes, for example, has shown that most states know virtually nothing about rates of compliance with building energy codes; in fact, most states make no effort to estimate them (Downs et al. 2013). And while federal lighting standards are considered a massive threat to savings potential, we showed earlier that states and utilities still consider lighting to be a huge source of savings potential over the next two decades. Questions remain, then, about codes and standards and the degree to which they affect remaining savings potential.

The Future of Potential Studies

In this section we discuss the future of energy efficiency potential studies, weaving together thoughts and ideas from interviewees with our own takeaways from our review. As reliance on energy efficiency as a system resource continues to grow as it has over the last decade, states and utilities will continue to seek out cost-effective savings opportunities.[25] However the state of energy efficiency programs is always in flux for a variety of reasons, so the assumptions and methodologies of potential studies will have to adapt accordingly.

Evolution of the Potential Study

Energy efficiency potential studies have become more common since 2000 and are now being used for a variety of purposes in energy system planning. According to our interviewees, these studies will continue to be an integral part of this process. However their rise in popularity has not created an equivalent increase in stakeholders' understanding of their mechanics. One interviewee noted that many stakeholders view potential studies as the last word in assessing the market for energy efficiency. As we have discussed, this is certainly not the case, particularly over a long period of time. To address this misconception, potential studies often present a range of possible scenario outcomes with the caveat that no one scenario gives the definitive answer. But only half the studies we reviewed analyzed potential across various scenarios. Still, despite the inherent uncertainty and inaccuracy in modeling market dynamics and customer behavior, potential studies can provide a snapshot of existing market conditions for energy efficiency, illustrating how savings potential can change as market conditions change, particularly in the short term.

Because of a lack of transparency, however, it is hard to discern the economy's impact on savings potential. Few of the studies we reviewed explicitly discuss macroeconomic impacts on market conditions. The impacts of the economy and other variables on customer participation are, as we learned, largely left to the judgment of the analyst and rarely defined quantitatively.

Nevertheless, there is always a concern that a weak economy could be detrimental to energy efficiency programs and savings potential. We know that customer participation in programs partly depends on customers' individual economic health. Several interviewees and a few studies noted that the drop in new construction rates during the Great Recession of 2008–2009 decreased the savings potential from these particular programs. But based on

[25] ACEEE's 2013 State Scorecard shows that utility program spending and budgets have been steadily increasing since 2000. See figure 2 in Downs et al. (2013).

the 45 studies we reviewed, it does not appear that the weak economy has had a negative impact on savings potential. In fact, ACEEE potential study meta-analyses conducted in 2004 and 2008 found the same levels and variation of savings potential estimates as those found in this report, despite the recession of 2008–2009.[26] Nadel et al. (2004) found a median annual savings of 1.2% for electric and 0.5% for natural gas; in this report we find a median annual savings of 1.3% for electric and 0.9% for natural gas. Conversely, we should note that there does not appear to be a significant increase in savings potential reported in studies going back to 2000. However ACEEE has not conducted any statistical analyses to corroborate these findings.

The fact remains that in the face of changing market conditions, stakeholders should revisit potential studies every several years; according to one interviewee, approximately every five years appears to be common. The economy is cyclical, and the majority of assumptions and inputs in a potential study are subject to economic forces. Energy prices, customer participation, utility avoided costs, discount rates, and so forth all depend on the state of the economy, and, as we have learned, changes in certain assumptions can have a considerable impact on overall potential results. Energy policies also change, new building codes are adopted, and new technologies are commercialized. Studies should be updated regularly to reflect all these changes. Their shelf life is necessarily short.

Interviewees noted that potential studies can be effective tools for short-term program planning; in fact, an increasing number of potential study RFPs focus on program design. However, while many of the studies we reviewed had some programmatic focus, it was generally limited to identifying cost-effective efficiency measures or informing program budgets. Only a handful of studies contained any direct recommendations on how program design should reflect insights gleaned from study results. This could be due to the evolution of utility programs from their initial focus on low-hanging fruit to more mature stages of implementation, and the challenges of achieving higher levels of savings over time.

Authors explicitly discussed program implications in all our ten case studies except the Idaho Power and Xcel Energy Colorado studies. Several interviewees also noted that potential results were being used to inform program design outside the potential study process. Growing interest in the programmatic implications of savings potential is likely a result of the growing number and maturity of energy efficiency programs across the country. As states and utilities continue to expand their program portfolios, we should see more potential studies being published to help identify savings opportunities in the context of program design.

As more utilities use potential studies to inform program design, then studies should increasingly reflect the evolution of program delivery efforts and their potential to catalyze increased measure uptake. Program administrators are constantly testing and using new ways of design, marketing, and delivering their programs in order to bolster participation. They are casting a wider net to increase program participation and savings without the need

[26] See figure 4 in Nadel et al. (2004) and table 1 in Eldridge et al. (2008).

for higher incentives, using such strategies as community-based marketing, midstream and upstream incentives, and multiyear planning with large customers. ACEEE has published a number of reports on program-design best practices used by utilities and third-party administrators.[27] A handful of the studies we reviewed for this report incorporate "enhanced program delivery," although none is explicit about what this entails. Future potential studies should acknowledge the impact on savings potential of improvements to program design and be explicit about the quantitative relationship.

Potential studies must also adjust their methodologies and assumptions to reflect changes in program design with respect to eligible measures. One interviewee noted, for example, that as program administrators strive for deeper, more sustained savings, energy efficiency programs are evolving away from rebating individual measures to a whole-building and systems approach. Given the long-term nature of mortgages and other financing mechanisms, programs that take a whole-building approach have much longer payback periods, so the economics of payback are not really the primary driver. Customers are investing in energy efficiency for other reasons including the marketability of buildings and properties. Recent ACEEE reports have focused on whole-system efficiency and the related topic of intelligent efficiency as they are becoming increasingly important in the programmatic landscape.[28]

Another interviewee noted that potential studies are gradually placing more of a focus on nontraditional energy efficiency measures such as customer behavior and feedback programs, demand-response resources, and CHP. The majority of studies we reviewed considered at least one of these nontraditional measures. Twenty-two of the studies included some analysis of potential savings from behavior programs or measures. But the focus was on soft, non-equipment measures, and there was little discussion on how behavior programs could be leveraged to bolster participation in other energy efficiency programs. Nineteen studies evaluated demand-response programs and measures, and 14 analyzed potential savings from CHP, although in both cases this analysis was more prevalent in studies with a time period of 16 years or more. Few of the studies that focused on the short term included analyses of demand response and CHP.

FUTURE RESEARCH NEEDS

This report discusses a number of areas where there are opportunities and needs for future research, and external reviewers offered further suggestions. These areas include the following:

- Program participation rates for common program types (e.g., residential home retrofits and new construction) across states and utility service territories

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[27] See York et al. (2013) and Nowak et al. (2013) for discussions of enhanced program design methods. ACEEE will also be publishing a report on high participation and the program design elements that program administrators incorporate in order to bolster participation.

[28] See Kwatra and Essig (2014) for a discussion of system efficiency in the context of comprehensive commercial building retrofits. See Rogers et al. (2013) for a broader discussion of the issue of system efficiency.

- The impact of codes/standards and ETs on savings potential
- Savings potential from lighting identified by recent potential studies
- Utility avoided costs, the methodologies and assumptions used in their quantification, and their impact on overall savings potential
- State policies regarding NEBs, the methodologies and assumptions used in their quantification, and their impact on overall savings potential
- Savings potential identified in studies compared to actual savings achievements in those states or utility service territories

Conclusions

Energy efficiency potential studies have been common for decades. But since 2000, they have moved beyond their traditional use as a tool for informing program design. They are increasingly integrated into long-term energy system planning and used as a resource for informing regulatory policy. Studies will likely proliferate as more states and utilities without much program experience expand their portfolios. Stakeholders need a better understanding of the mechanics of these studies and their limitations, how various methodologies and assumptions can impact savings potential, and how nuances make direct comparisons of studies difficult.

Median estimates of energy efficiency savings potential have not changed noticeably over the past decade or more, despite a major recession, a precipitous drop in natural gas prices, and the impacts of codes and standards. Our 2004 meta-analysis found a median annual savings of 1.2% for electric and 0.5% for natural gas (Nadel et al. 2004). In this report we find a median annual savings of 1.3% for electric and 0.9% for natural gas. It is clear that, for all the differences in study methodologies and assumptions, states and utilities are still finding a considerable amount of cost-effective energy efficiency savings potential after more than ten years. Given the inaccuracy of models and the generally conservative approach of these studies, there is likely a great deal of additional cost-effective potential available beyond what is identified. The evolution of program design can only enhance this potential.

Given the inherent inaccuracy of modeling and forecasting, particularly over long periods of time, potential studies are most informative when assessing potential in the short term. Studies can provide a snapshot of existing market conditions and, when coupled with recent historical program performance, they can help program administrators develop expectations about performance in the near future. This analysis breaks down once studies begin to consider time periods longer than five years or so. Moreover, given the fact that most studies base their customer-participation models on economics, even short-term forecasts of market dynamics are murky. This is because studies tend to downplay the impact of program design elements such as marketing and education, as well as the non-energy justifications for investing in energy efficiency.

These limitations certainly do not render potential studies useless. But they do elucidate the need for greater clarity and transparency. Whether intentionally or not, practically every study we reviewed lacked sufficient transparency when it came to discussing important variables such as participation, emerging technologies, and avoided costs. If potential studies are to continue to play a major role in energy planning, stakeholders must be able to scrutinize their methodologies in order to evaluate the veracity of the results. This transparency will lead to more active, constructive stakeholder discussions and more reflective assessments. It appears that potential studies will continue to be an important tool for energy system planning. But how useful a tool is entirely dependent on the amount of data and the degree of transparency the authors and their clients are willing to provide.

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Appendix A: Case Studies

In this appendix we examine ten studies in greater detail based on a combination of interviews with the authors and an independent examination of the study results. We discuss the studies' methodologies and assumptions with regard to the areas we covered in the body of the report on the qualitative results of all 45 studies. Our goal is to provide readers with some context and specific examples for the discussion in the qualitative results section. This will help them conceptualize how the assumptions we discuss in that section are incorporated into studies and their implications for overall potential results. We examine the following studies:

1. *Idaho Power Energy Efficiency Potential Study:* EnerNOC Utility Solutions
2. *CenterPoint Energy Minnesota Natural Gas Efficiency Potential* Study: Navigant Consulting, Inc.
3. *Achievable Energy-Efficiency Potentials Assessment* (Georgia Power): Nexant
4. *Colorado DSM Market Potential Assessment:* KEMA DNV
5. *Update to the Colorado DSM Market Potential Assessment (Revised):* KEMA DNV
6. *2013 California Energy Efficiency Potential and Goals Study:* Navigant Consulting, Inc.
7. *Electric Energy Efficiency Potential for Vermont:* GDS Associates, Inc. and The Cadmus Group, Inc.
8. *Assessment of Energy and Capacity Savings in Iowa:* The Cadmus Group, Inc.
9. *The $20 Billion Bonanza:* Southwest Energy Efficiency Project
10. *ComEd Energy Efficiency Potential Study Report, 2013-2018:* ICF International and Opinion Dynamics Corporation

IDAHO POWER: ENERNOC UTILITY SOLUTIONS

Note: In our interview with EnerNOC, we were unable to discuss the Idaho Power study specifically except in a couple of instances, so the information provided here is gleaned primarily from our independent review of the study. Our discussion with EnerNOC instead focused on its general methodological approach to potential studies.

Background

Idaho Power commissioned EnerNOC to conduct this study, published in 2013, for the purpose of identifying the available savings potential of its energy efficiency programs and to identify areas for refinement in order to enhance savings. In particular, Idaho Power sought to "quantify the amount, the timing, and the cost of electric energy efficiency resources" available in its service territory.

Discussion of Overall Results

In table A1 we present the overall results of the study. The analysis consists of two key levels of energy efficiency potential: technical/economic potential and achievable potential. EnerNOC assumes that about 53% of economic potential is achievable, one of the lower results for this metric (only 24 studies provided enough data to perform this calculation). The achievable potential analysis considers only one scenario and does not elaborate on the level of incentives assumed or other associated program costs. There are also no estimates of program portfolio cost effectiveness or the expected net benefits or costs of the achievable potential scenario. Overall, EnerNOC found that, through 2032, Idaho Power could achieve a maximum achievable potential of 12.2%, or an annual average of about 0.6%. EnerNOC did not evaluate the cost effectiveness of its achievable potential scenario.

Table A1. Overall results, Idaho Power, 2012-2032

Year	Analysis period (years)	Electricity potential (% of sales)						TRC b/c ratio	TRC benefits (million $)	Avoided costs ($/kWh)*
		Tech	Econ	Maximum achievable						
				Low	Mid	High	Average annual			
2012	21	37.4%	22.8%			12.2%	0.6%			$0.029 - $0.053

* Avoided costs were derived from Figure 2-4 in the EnerNOC study, so these are rough estimates. The range is a forecast of avoided energy costs between 2012 and 2032. EnerNOC defines avoided costs and avoided energy and (peak) capacity only.

Review of Methodologies and Assumptions

EnerNOC's methodology for estimating customer participation is standard, conducted primarily using secondary resources. In this study for Idaho Power, EnerNOC was required to use ramp rates from the most recent Power Conservation Plan developed by the Northwest Power and Conservation Council. Ramp rates are the rates at which participation escalates, defined as "market adoption factors" in the Idaho study. EnerNOC typically modifies ramp rates over the first few years of the forecast to reflect utility program accomplishments, as it did for this study. (We are unsure about the directional impact.) However EnerNOC aligns with the council's ramp rates in the out years of the forecast. The ramp rates are applied on an annual basis to the economic potential for each energy efficiency measure. Ramp rates for each measure are reported in the study's appendices.

Codes and standards are incorporated into baseline projections of energy consumption by customer segment and end-use. Only existing codes are factored into projections, while expected federal equipment standards are taken into account at the measure level. There is no additional information provided on the magnitude of the impacts of codes and standards over the study time frame, which is not unusual given the focus of the study on informing program development. However there is no discussion in the study of the impacts of federal standards on savings potential, particularly relative to lighting. The majority of studies we reviewed included at least some mention of federal lighting standards.

EnerNOC's study found a considerable amount of potential savings from lighting in the residential and commercial sectors over the study period. For residential, the highest potential reported was in the earlier years: 67% of total residential achievable potential in 2015 is from lighting, falling to 59% in 2017 and to 23% in 2032. The percent of total commercial achievable potential stemming from lighting is more static: 48% in 2015, 46% in 2017, and 50% in 2032. These results imply that EnerNOC is not expecting a large loss of cost-effective energy savings from lighting over the next several years, although potential in the out years of the study is quite low for the residential sector.

In part this could be due to how EnerNOC treats emerging technologies in the study. In our interview, EnerNOC noted that the definition of emerging technologies can vary. Some technologies that are new and gaining hold in the marketplace, such as heat-pump water heaters and LEDs, might have been considered emerging technologies when this study began a few years earlier. The list of measures in the appendices of the Idaho study includes both of these technologies, but it is unclear to what extent they are contributing to savings potential. The study assumes that residential and commercial LED measures are not cost effective until 2020, and even by 2020 not all LED applications are estimated to be cost effective.

This could explain why potential in the out years is relatively low for lighting for the commercial sector. The increase in annual achievable savings potential in the commercial sector is lower between 2027 and 2032 than for any other five-year period reported: annual achievable savings potential increases by 85% for the 2017-2022 period, the 2022-2027 period shows a 43% increase, and the 2027-2032 period shows a 24% increase (see table 5-11 in the study). Results are noticeably different for the residential sector: annual potential over the 2017-2022 period actually decreases by 25% (presumably due to the full implementation of federal lighting standards); savings potential then increases by 9% over the 2022-2027 period and increases again by 97% over the 2027-2032 period (see table 5-4). This raises several questions about the treatment of LEDs over time and across the two sectors, while the five-year benchmarks make it more difficult to understand the timing of the assumptions.

The avoided costs used in the study were provided by Idaho Power. EnerNOC reports its assumptions for avoided costs, which is unusual within the ten studies we reviewed in this section as well as for the larger 45-study sample. EnerNOC defines its avoided costs assumptions only as avoided energy and (peak) capacity costs. The avoided costs reported are relatively low compared to the other ten studies we reviewed that reported avoided costs. This likely has an impact on savings potential, particularly in the out years: LED lighting does not become cost effective until 2020, but avoided costs are projected to increase only to $0.055/kWh by 2032, according to figure 2-4 in the study. The levelized cost estimates for LEDs, included in the study's appendices, rarely approach the $0.055/kWh threshold for the residential sector, while cost-effective applications in the commercial sector are a bit more common.[29] The study did not explain the various components of the avoided cost values, which is a common trait across all of the studies we reviewed.

EnerNOC's study included a line item in its achievable potential results for behavioral feedback tools, but no savings were reported for this measure.

Given that the ultimate use of the study is to inform program development, it is unusual that EnerNOC did not report any results for program costs, which would be used to inform program budgets. Reporting these costs would also give readers the opportunity to

[29] Of the 12 technical applications in the residential sector, LEDs were only cost effective in 2 of those applications: interior and exterior screw-in applications for bulbs of 197 lumens per watt. Of the 12 technical applications in the commercial sector, LEDs were only cost effective in 5 of those applications: replacing interior and exterior screw-ins in 2020, replacing interior high-bay fixtures in 2020, and replacing interior and exterior linear fluorescent bulbs in 2020. The contribution to overall savings potential of these individual applications is unknown.

understand how EnerNOC assumes total program costs will be allocated across incentive and non-incentive costs, such as marketing, and how the cost allocation changes over time to reflect program maturity and measure saturation.

Observations

EnerNOC's methodologies for modeling customer participation and the incorporation of codes and standards are standard practice. EnerNOC lists annual market adoption factors in Appendix F; however, it only provides data through 2025: for equipment measures (lighting, electronic, appliances, etc.) participation is capped between 16%-40%, while for non-equipment measures (insulation, windows, air-conditioning maintenance, etc.) participation is capped between 49%-63%. However the relatively low achievable results of EnerNOC's study for Idaho Power raises some questions, particularly the role of emerging technologies in the out years and the components of Idaho Power's avoided-costs assumptions. Given the long time frame of the study, emerging technologies are included, but more information on the savings potential from emerging technologies would be helpful, especially considering the drop in lighting potential in the out years. Some measure-level information can be gleaned from the study's appendices, but the overall contribution of emerging technologies to savings potential is unclear. It is also uncertain the types of avoided costs that Idaho Power incorporates into its calculations and why avoided costs are assumed to increase only slightly over the 21-year study period.

CenterPoint Energy Minnesota: Navigant Consulting, Inc.

Background

The natural gas energy efficiency potential analysis completed by Navigant Consulting, Inc. (Navigant), published in 2014, was commissioned by CenterPoint primarily to address cost-effectiveness issues that had arisen since the publication of its 2009 study, such as low natural gas prices. New measures were also added to the analysis, including emerging technologies. The scenario analysis considers various program design options to understand how potential varies under certain conditions, with the expectation that the least cost scenario that allows CenterPoint to meet its mandated savings targets will be pursued during the next program planning cycle. The analysis looks through 2025, but reports results for benchmark years with a focus on 2018, which is the end of Minnesota utilities' next program cycle. Additionally, Minneapolis is considering municipalization, so the analysis also estimated potential for the Minneapolis area specifically. The model developed for the study is capable of producing additional outputs and scenarios results beyond those presented in the final report. The model can report annual and cumulative saving by sector, end use, and measure for each scenario every year from 2010 through 2025. Additional program costs and cost effectiveness can be produced by the model.

Discussion of Overall Results

In table A2 we present the overall results of the study. The analysis consists of two key levels of energy efficiency potential: technical/economic potential and market (achievable) potential. The market potential analysis considers five different scenarios (1-5) that assess impacts based on either low, mid, or high cases for five primary variables: incentive levels; addition of new measures and emerging technologies; enrollment in behavioral programs; enrollment in non-conventional measures (fuel switching and combine heat and power);

and enhanced program delivery. At the behest of CenterPoint, Navigant did not assume incentive levels set any higher than 60% of incremental costs.

We report values for scenarios 1, 3, and 5, as we believe these scenarios are the best reflection of low, mid, and high cases.[30] Minnesota uses the Societal Cost Test to quantify measure and program cost effectiveness, and while Navigant's model provides these data, the benefit/cost ratios or economic benefits are not highlighted in the report. Only annual savings in 2025 are reported in the main body of the study, which Navigant estimates at 1.51%, 1.61%, and 2.23% for scenarios 1, 3, and 5. The maximum achievable values in Table A2 below do not reflect annual averages over the study period.

Table A2. Overall results: CenterPoint Energy Minnesota (2015–2025)

Year	Analysis period (years)	Natural gas potential (% of sales)						SCT b/c ratio	SCT benefits (million$)	Avoided costs ($/kWh)
		Tech	Econ	Maximum achievable*						
				Scen. 1	Scen. 3	Scen. 5	Average annual			
2014	11			1.51%	1.61%	2.23%				

*Navigant's study only reported annual savings for benchmark years. No cumulative values were provided, as Minnesota states its goals on an annual, not cumulative, basis. In this table we report annual savings in 2025. These values do not reflect annual averages over the study period.

Review of Methodologies and Assumptions

CenterPoint's potential study is one of the most comprehensive and transparent of the 45 studies we reviewed. The analysis of market potential considers a number of scenarios where a number of key variables are allowed to change, thereby providing a more comprehensive picture of energy efficiency potential. However, incentive levels do not increase above 60% of incremental costs in any scenario, which is conservative: ACEEE research has found that it is common for incentives to constitute upwards of 80% of incremental costs.[31] Overall, the average annual savings reported in each of the five scenarios are at least on par, if not slightly more aggressive, than historical program achievements in most other states.

Navigant relies on existing data for estimating future customer participation rates and is quite transparent about its methodology and assumptions. Adoption of a specific measure is

[30] Scenarios 1 and 2, for example, only differed in their assumptions about incentive levels, which were "low" and "mid," respectively. Scenario 2 is the only scenario that assumed "mid" levels of incentives. Scenarios 3 and 5 assumed "high" levels of enrollment in non-conventional measures and enhanced program delivery, although scenario 3 assumed "low" levels of incentives. Table 13 in the study shows how assumptions vary across the five scenarios.

[31] M. Molina, *The Best Value for America's Energy Dollar: A National Review of the Cost of Utility Energy Efficiency Programs*, Washington, DC: ACEEE, 2014, http://www.aceee.org/research-report/u1402.

estimated from an economic perspective, i.e., a measure's simple payback, which, together with industry standard payback acceptance curves, is used to forecast the ultimate market penetration of a technology. Navigant also uses participation rates from existing programs to calibrate estimates of participation in the short term (up to five years). In addition to economic variables, Navigant allows payback acceptance curves to shift based on program design efforts, or "enhance program delivery," defined as low, mid, or high; i.e., increases in non-incentive program costs increase participation for any given payback period. Navigant assumes low enhanced program delivery in its business-as-usual scenario, mid enhanced program delivery for Scenarios 1 and 2, and high enhanced program delivery in Scenarios 3, 4, and 5.

Energy savings from existing codes and standards are incorporated at the measure level, but the sales forecast used in the study, provided by CenterPoint, does not account for future savings from codes and standards because of the uncertainty of effective dates and efficiency levels. The study does not estimate savings attributed to codes and standards, as CenterPoint does not claim savings from codes and standards toward its goals. The study also adds new measures and emerging technologies at varying degrees across the five scenarios, although the low case assumes none of these emerging measures are included.

Minnesota requires use of the Societal Cost Test and the state has created a standard cost-effectiveness template that utilities must use to estimate program and measure cost effectiveness as well as utility avoided costs. The template, which is publically available, assumes that avoided costs include nonfuel (O&M) variable costs and gas commodity costs (which escalate over time), a value for peak demand savings of natural gas (tied to storage and/or pipeline infrastructure) as well as a 35% benefits multiplier to account for the environmental costs of natural gas supply (which also escalates over time, albeit at a slower rate than commodity costs). The template includes a way to value electric savings from gas measures, but it is rarely used.

Observations

Overall, Navigant's analysis is robust and transparent. Its methodology for forecasting participation is industry standard best-practice. The study estimates the effects of emerging technologies in a few scenarios and, while codes and standards are only incorporated at the measure level, the purpose of the study is to inform program design in the short term, so the paramount concern is estimating future savings potential attributable to program efforts. The use of the Societal Cost Test is fairly unique and the incorporation of an environmental damage factor likely has a measurable impact on overall potential.

GEORGIA POWER: NEXANT

Background

The Georgia Public Service Commission (PSC) requires a triennial IRP process for its utilities, for which potential studies are the initial part of that process, conducted one year in advance of a utility's IRP filing with the Georgia PSC. In addition to informing the IRP process, the results of Georgia Power's study, published in 2012, are used to assist in targeting DSM programs in areas where the highest market potential exists while complying with the PSC's mandated goal of balancing economic benefits while minimizing pressure on rates. Georgia has formed a DSM Working Group, which Georgia Power regularly engages throughout the process. This working group is something that is very unique among the studies we reviewed. The study is an update to the previously published iteration in 2007.

Discussion of Overall Results

In table A3 we present the overall results of the study. The analysis consists of two key levels of energy efficiency potential: technical/economic potential and achievable potential. The achievable potential analysis assesses three different scenarios that vary by incentive levels: 25%, 50%, and 100%. Nexant estimates that, through 2023, the low, moderate, and high scenarios could generate 6.1%, 9.3%, and 15.3% of cumulative savings with an overall portfolio cost effectiveness of 2.4, using the TRC test, and net TRC benefits of almost $6 billion.

Table A3. Overall results: Georgia Power, 2012–2023

Year	Analysis period (years)	Electricity potential (% of sales)						TRC b/c ratio	TRC benefits (million$)	Avoided costs
		Tech	Econ	Maximum achievable						
				Low	Mid	High	Average annual			
2012	12	26.5%	22.2%	6.1%	9.3%	15.3%	1.3%	2.4	$5,733	

Review of Methodologies and Assumptions

Nexant models customer participation using a combination of secondary resources on program performance, both national and regional, in particular program savings, cost, and participation data from the U.S. Department of Energy's Energy Information Administration (EIA) and individual program evaluations. Nexant approaches the analysis by first determining the elasticity between incentive levels and savings (EIA data) and then determining base participation by reviewing utility program evaluations. This information is used to develop market penetration curves for each end use. No additional information is provided on assumed participation levels over time, either quantitatively or qualitatively.

In the study, Nexant notes that customer participation is a key determinant in savings potential, but modeling participation involves a "high level of uncertainty." Nexant noted in an interview that, indeed, the assessment of market impacts over time is the most imprecise aspect of the report, or any potential study for that matter. Additionally, Nexant shared that marketing and outreach are essential elements to its participation models and that it takes these impacts into account at the portfolio level. However it is not clear that this is the case in the study, as it appears that the greatest determinant of customer participation is economics, at least at the measure level. The study does not disaggregate program expenditures by category, either, except in charts related to its benefit/cost calculations, so it is impossible to know how non-incentive costs such as marketing change across scenarios and what impact increasing budgets for marketing have on savings potential.

Current and pending codes and standards are incorporated into baseline forecasts, while standards were also incorporated at the measure level. Nexant does not consider emerging technologies in the study, but this is due to the relatively short-term outlook of the report in light of its focus on informing short-term program design. However, to the extent that the study is used in Georgia's IRP process, excluding emerging technologies likely has some measurable impact on savings potential, particularly in the medium to long term. The study also does not examine the potential impact of behavior programs.

Nexant reported one of the lowest values for lighting potential in the residential sector across the studies we reviewed: 11% of total maximum achievable potential. Nexant reports that this is due to federal lighting standards, but there is no further explanation about the timing and overall impact of the standards on potential, such as the assumption that CFLs are considered the baseline or that they suffer from high free-ridership rates that lower cost-effective achievable savings. Commercial lighting potential was more on par with results from other studies: 50% of total commercial maximum achievable potential comes from lighting.

Avoided costs were supplied by Southern Company, which, according to the authors, has a sophisticated model for quantifying avoided costs that goes beyond the standard fuel and O&M costs that typically comprise utility avoided costs, including hourly profiles of supply and demand resources and how efficient measures are dispatched over time. Avoided costs estimates include water benefits, but this may only be at the measure level (efficient clothes washers). Otherwise, avoided costs appear to consist only of avoided energy and capacity costs, from what can be gleaned from the text. There is no discussion of the inclusions of environmental externalities or other non-energy benefits, which likely has some impact on overall potential results, though Nexant did consider gas benefits at the measure level.

Observations

Nexant's study is strong and its engagement with stakeholders sets a high standard for public engagement in potential studies. Its methodologies for estimating customer participation are industry standard and Nexant takes the time to explain the inherent uncertainty of its forecasts. Despite the exclusion of emerging technologies, the exclusion of non-energy benefits in the calculation of avoided costs, and low lighting potential estimates in the residential sector, the study finds a considerable amount of savings potential over the 12 year study period. However changes to these variables could go a long way toward increasing maximum achievable potential over the 1.3% annual average that the study reports.

Xcel Energy Colorado 2010 and 2013 Market Potential Assessments: KEMA DNV

Background

Xcel Energy Colorado (Xcel) commissioned its 2010 potential study in an effort to inform its subsequent Biennial Plan, which was filed in 2010. The goal of the study was to determine the level of DSM savings available in Xcel's Colorado service territory, the costs associated with procuring those savings, and the cost effectiveness of those savings measures, focusing on the time period from 2010 to 2020. Its 2013 study was commissioned to update the 2010 iteration, focusing on the 2013 to 2020 time period. The 2013 study updated a number of assumptions and inputs including electric avoided costs for both energy and capacity; measure saturation to reflect three years of program activity; discount rates, inflation rates, and line loss rates to reflect the latest assumptions; and lighting measures to better reflect national lighting standards and to better incorporate LED technologies.

Discussion of Overall Results

In table A4 we present the overall results of the studies. Both studies include analyses of technical, economic, and achievable program potential. KEMA assumes that 76% and 53% of the economic potential are achievable in the 2010 and 2013 studies, respectively, the latter of which is fairly low relative other studies that provided this data (only 24 studies provided enough data to perform this calculation). The achievable program potential analyses consider three different funding scenarios that vary by the level of incentives: 50%, 75%, and 100%. Across the two studies KEMA reports that, in light of the updated assumptions mentioned above, savings potential increased in the 50% and 75% scenarios by 4% and 8%, respectively, although potential decreased by 2% in the 100% scenario. In the 2013 study, KEMA does not report cumulative or annual savings for either the low or mid scenarios. Overall, through 2020 KEMA found similar average annual potential in both studies with similar results for portfolio cost effectiveness. KEMA reports that the increase in savings across studies is primarily due to the addition of LEDs, while any decline in savings is primarily a result of the increase in saturation of energy efficient measures due to Xcel's programs.

Table A4. Overall results: Xcel CO, through 2020

Year	Analysis period (years)	Electric potential (% of sales)						TRC b/c ratio	TRC Benefits (million$)	Avoided costs** ($/kWh)
		Tech	Econ	Maximum achievable*						
				Low	Med	High	Average annual			
2010	11		23%	6.4%	10.1%	17.5%	1.6%	2.8	$4,166	$0.06 - $0.085
2013	8	33%	23%			12.1%	1.5%	2.5	$2,639	$0.047 - $0.089

* Maximum achievable savings potential for the 2010 study is calculated based on data provided in the text of the studies. KEMA reports economic potential as a percentage of base 2020 energy use. Achievable potential for the low, mid, and high scenarios are reported as percentages of economic potential, or 28%, 44%, and 76% of the economic potential respectively. In the 2013 study, KEMA reports technical and economic potential in the text as percentages of base 2020 energy use. ACEEE had to contact the study author in order to estimate achievable potential. ** Avoided costs for the 2010 study represent the forecasted range for 2010 through 2020, assuming base avoided costs for summer and winter on-peak, and were derived from charts instead of taken directly from a table. Both summer and winter on-peak values were roughly the same, within a few thousandths of a cent (see figure 3-4 in the study). In the 2013 study, avoided costs are for the years 2013–2032 as reported in the first table in Appendix A.

Review of Methodologies and Assumptions

KEMA defines its "achievable program potential" scenario as the "amount of savings that would occur in response to specific program funding and measure incentive levels." While the scenarios appear to be defined by incentive levels, in its methodology section it notes that customer adoption of energy efficiency measures is contingent upon program design efforts as well; i.e., higher spending on marketing leads to higher levels of awareness and, ultimately, adoption.

However the study could provide additional information on how it models customer participation (adoption) over time and how participation curves are adjusted given changes in incentive or non-incentive costs. The study does not provide quantitative data regarding participation rates and simply notes that marketing and incentives influence participation without any additional discussion on how participation varies across scenarios. Discussions with KEMA revealed that marketing budgets drive its participation model, while incentive levels and administrative budgets are also outputs of its participation model. KEMA explains the importance of marketing in the study, but the assumption that marketing is a primary factor is not conveyed and, in fact, appears to be contradicted in its tables reporting program spending across scenarios. KEMA reports its assumed costs for each scenario, including the disaggregation of incentive and non-incentive costs. KEMA assumes that, between the 50% and 100% incentive scenarios, marketing costs increase by 12% and 10% in the 2010 and 2013 studies, respectively. Meanwhile, administrative costs increase by almost four times across incentive scenarios in both studies (382% and 397%) and incentive costs by over six times in 2010 (619%) and eight-and-a-half times (866%) in 2013. Without a greater understanding of how marketing is incorporated into its model, it appears that the primary driver of participation is incentives, not marketing.

Both studies model savings from behavior programs and emerging technologies, though these areas are examined independently from the achievable program potential scenarios; i.e., savings from these areas are not included in the savings reported above in table A4. In 2010 the behavioral analysis considered savings from both direct and indirect feedback measures, while the 2013 study only considered indirect feedback measures due to the lack of advanced metering systems that are required for direct feedback measures. KEMA did not include a discussion on how behavior programs could influence participation in other Xcel programs. Furthermore, there is no discussion on how these results can be used to inform program design efforts, despite the purported importance of marketing in forecasting customer participation.

KEMA's treatment of emerging technologies varies noticeably across the two studies. KEMA considered a greater number of ETs in 2010 than in 2013, for example, and it also provided a more detailed discussion about the analysis in its 2010 study. In 2010, KEMA focused on a handful of measures, including LEDs (residential and commercial, including street lighting), fiber-optic refrigeration display lighting, and indirect evaporative cooling for the residential sector. In 2013, KEMA focused mainly on LED lighting, noting that traction for evaporative cooling has not materialized as expected. LEDs are also treated differently across the two studies: in the 2010 study, KEMA assumes equipment costs that would make ETs economically viable and therefore reports the achievable potential savings associated with those ETs; however, in 2013, KEMA assumes that the costs of LEDs are prohibitive and does not report the achievable potential savings associated with LEDs. In the 2010 study ETs comprise 21% of total economic potential compared to 16% in the 2013 study. In the 2010 study, ETs contribute an additional 6%-16% achievable potential savings between the 50% and 100% scenarios; not an insignificant amount.

Assumptions about avoided costs also changed across the two studies. Both studies assume some additional benefits to account for environmental externalities and other non-energy benefits (10% adder for NEBs, albeit 20% for low-income). Otherwise, avoided costs appear to consist only of avoided energy and capacity costs, as well as avoided commodity costs for natural gas. In 2010, avoided costs varied by time-of-use (summer/winter, on/off-peak), but in 2013 only one value was used across all time-of-use periods. Additional updates to the avoided cost assumptions lowered avoided costs on average between the 2010 and 2013 studies, which caused downward pressure on potential estimates: economic potential dropped 23% between the two studies, when comparing the 2010 base avoided-cost scenario to the new, lower avoided-cost scenario in the 2013 study.

Both studies included analyses of the impact of higher avoided costs on potential—where the base values for avoided costs are those estimated in the 2010 study—though the 2013 study focused only on the impact to economic potential. In the 2010 study, KEMA assumed the high avoided cost scenario was 35% higher than the base forecast, which resulted in higher achievable potential savings in the 50% and 75% incentive scenarios (an extra 10% and 6%, respectively) and a lower achievable potential savings in the 100% incentive scenario (-1%). In 2013, lower avoided costs decreased economic potential by almost 6%, though KEMA does not report the percentage change in avoided costs for comparison.

Observations

The two KEMA studies are comprehensive and stand out from other studies in a handful of ways, particularly due to the inclusion of emerging technologies and the incorporation of environmental externalities and non-energy benefits in estimates of avoided costs. However the absence of ETs in the 2013 study beyond LEDs, which were assumed not to be cost effective and therefore did not contribute to achievable savings potential, is troubling. For instance, it is uncertain if customer reluctance to adopt evaporative cooling equipment is due to economics or program design elements. Given that ETs contributed up to 16% of total achievable potential in the 2010 study, they are clearly important and warrant at least a greater discussion regarding their exclusion in the 2013 study.

The studies also do not appear to value the contribution of program design to savings potential, even though marketing expenditures are the primary driver of participation in KEMA's model. Reported program costs convey that incentives are the primary driver of participation, given the relative increase in costs across incentive scenarios for marketing and incentive costs. It is possible that each dollar invested in marketing has a greater return in terms of participation than does each dollar of incentives, but if that is the case, it is not explained.

2013 California Energy Efficiency Potential and Goals Study: Navigant

Background

Navigant's potential study for the state of California, published in 2013, was commissioned by the California Public Utilities Commission (CPUC) primarily to inform the 2013-2014 goal-setting process for California's investor-owned utilities. In addition to setting goals, the cumulative savings results from the study were utilized by the California Energy Commission (CEC), which establishes the demand forecast for long-term procurement planning, as well as the California Independent System Operator (CAISO). These two entities had previously not incorporated long-term energy efficiency into their long-term forecasts, but the robustness of Navigant's methodology convinced them otherwise. The CEC's demand forecast is an input into the CPUC's Long-Term Procurement Planning proceeding, which determines the generation resources that energy efficiency is expected to offset. The study also provides guidance for the IOUs' 2015 energy efficiency program portfolios. The study results are being used in various other utility research and planning activities, though it is not being used to set goals for the 2015 program year. The model developed for the study is capable of producing additional outputs and scenarios results beyond those presented in the final report. The model can report annual and cumulative saving by utility, sector, climate zone, end use, and measure for each scenario every year.

Discussion of Overall Results

In table A5 we present the overall results for the study, for which electricity savings are estimated in terms of gross impacts. The study includes analyses of technical, economic and "market potential," the latter of which is evaluated across three scenarios: low, mid, and high. Table 2-18 in the study outlines the assumptions for the three market potential scenarios, showing that incentive levels in the low and mid scenarios are set to 25% and 50% of measure incremental costs, respectively, while incentive levels in the high scenario vary by "market maturity." In other words, measures with the lowest market saturation (<= 5%) are rebated at 100% of incremental costs and those with the highest market saturation (> 75%) are rebated at 50% of incremental costs.

Table A5. Overall results: California IOUs, 2013–2024

Year	Analysis period (years)	Electric potential (% of sales)*						TRC b/c ratio*	TRC benefits (million$)*	Avoided costs*
		Tech	Econ	Maximum achievable						
				Low	Med	High	Avg annual			
2013	12									

* No data available

Review of Methodologies and Assumptions

The study is unique in several of its assumptions and methodologies. For example, Navigant varies the cost-effectiveness threshold for measures across the three market potential scenarios to relax the standards as the state pushes for deeper savings. The TRC threshold is assumed to be 1.0 in the low market potential scenario, 0.85 in the mid scenario, and 0.75 in the high scenario. The TRC threshold for ETs is also relaxed, in part due to the uncertainty of costs and savings of ETs in the future. In the low scenario, the threshold is set at 0.85, 0.5 in the mid scenario, and 0.4 in the high scenario. Navigant also examined the impact of energy efficiency financing mechanisms on market potential, noting that financing lowers upfront costs, which increases market adoption of measures. While no primary data were collected, Navigant used extensive existing data, both internal and external, to inform its models.

Navigant noted that its methodology for projecting customer participation rates is a bit more sophisticated in this study than in previous Navigant studies, in part because of its analysis of energy efficiency financing. Mechanisms for financing energy efficiency investments, particularly for costlier projects (e.g., whole building retrofits), are usually contracted for many years, if not decades, so the traditional method of using simple payback is not helpful in order to evaluate the impact of financing on savings potential over the long term. Therefore, Navigant uses a levelized cost approach, noting its effectiveness in capturing the effects of financing as well as allowing for competition of multiple measures with different estimated useful lives for each end use. Navigant's model uses a dynamic Bass Diffusion approach to simulate market adoption, which assumes participation is influenced by areas such as marketing, education, and outreach, word of mouth, and willingness (i.e., once a customer is aware of a program, how do the economics of the measure influence the purchasing decision). Navigant then calibrates the results from this modeling exercise using program portfolio data from 2006 through the 2013–2014 IOU compliance filings, adjusting the willingness and awareness parameters to account for historical experience. Ultimately, these factors generate participation rates that vary across scenarios in five levels: low, low-mid, mid, high-mid, and high; no quantitative data are provided. Navigant provides a detailed discussion of its methodology and assumptions in the study.

Navigant's model for the treatment of codes and standards is a very detailed, quantitative approach. Codes and standards are modeled to impact the baselines of utility rebated measures, thereby decreasing their potential savings. Utilities in California are allowed to claim savings credit from efforts to support codes and standards, however, so the model increases the savings that utilities can claim from related activities. The model is built to forecast future savings from codes and standards under various scenarios, detailing when codes may come into effect and their impact on savings.

Navigant takes a unique, systematic approach to modeling ETs, focusing on the residential and commercial end uses that account for the largest energy use. It found that 12 electric end uses account for 83% of residential and commercial electric consumption, while seven gas end uses account for 87% of residential and commercial gas consumption. Navigant then determined the range of possible ETs for those 19 end uses, consulting its own internal databases as well as external resources such as the U.S. DOE and the California Database for Energy Efficiency Resources (DEER). Navigant then applies a risk factor to each ET so as to account for the uncertainty of ETs to create those expected savings. Navigant then developed four cost reduction profiles to apply to the various ETs, in particular gathering data specific to LEDs in order to capture their expected reduction in costs and improvement in performance over time.

The impact of behavior programs is included in the study, although Navigant's modeling and estimates of savings do not differ from the 2011 iteration of this study due to uncertainties in forecasting savings over time, particularly beyond the current program cycle. Navigant notes that there are two types of savings from behavior programs—usage based and equipment based—and that disaggregating the total savings from the two types is difficult and has not yet been adequately researched. IOUs in California can only claim usage-based savings, as equipment-based savings are assumed to happen when customers are driven toward rebate programs. The ability to forecast these two types of savings over time is important and California's IOUs are currently working collaboratively to develop a consistent model for future use.

The avoided costs used in the study are derived from Energy+Environmental Economics (E3) avoided-cost model, which was developed for the CPUC and is publically available on E3's website. Avoided-cost assumptions are utility specific: the model is Excel-based and allows for individual customization by utilities. Navigant, again, is quite unique in its approach for incorporating avoided costs: avoided costs vary depending upon the scenario (low, mid, high). Avoided costs are, therefore, utility specific and are not specifically reported in the study. The CPUC requires avoided costs to include avoided capacity costs, avoided T&D, and avoided fuel costs. In our interview with Navigant, however, study authors noted that avoided emissions costs are included ($/ton or $/lb), which is clear when reviewing the CPUC's approved model on E3's website.

Observations

Navigant's study for California is very technical and provides clear, detailed discussions on its assumptions and methodologies. Compared to other reports we reviewed, its scope and methodologies are fairly unique and rigorous, which is clear given the incorporation of the study's results by the CPUC, CEC, and CAISO, as well as by IOUs who intend to use some of the study's findings to inform their program development efforts. Its model for forecasting customer participation is unlike any other of the nine studies we reviewed for this section. Unlike many of the other studies we reviewed, Navigant goes to great lengths to incorporate ETs into its analysis.

ELECTRIC ENERGY EFFICIENCY POTENTIAL FOR VERMONT: GDS ASSOCIATES, INC.

Background

Vermont's latest energy efficiency potential study, commissioned in 2010 and published in 2011, was conducted by GDS Associates, Inc. in partnership with the Cadmus Group, Inc. for the purposes of informing targets, budgets and goals for the State of Vermont and its two energy efficiency utilities (EEU): the Burlington Electric Department (BED) and Efficiency Vermont (EVT). Vermont's EEUs are responsible for the energy efficiency programs that provide services to customers of Vermont's 21 utilities. In the study GDS notes that potential studies are "important and helpful tools for identifying those energy efficiency measures that are the most cost-effective and that have the most significant electricity savings potential." In addition to identifying measure opportunities for energy efficiency programs in Vermont, the achievable potential results were inputs into an additional analysis that considered three resource portfolios scenarios to determine the portion of the achievable potential that might be achieved given a specific funding level and program design.

Discussion of Overall Results

GDS conducts analyses for technical, economic, and achievable potential, acknowledging that the latter is often referred to as maximum achievable potential. GDS assumes that 87% of economic potential is achievable, one of the higher results for this metric relative to other studies (only 24 studies provided enough data to perform this calculation). Its definitions of the three potential levels are standard, with cost effectiveness estimated at the measure and portfolio level using the Societal Cost Test. There is only one (maximum) achievable scenario, in which GDS assumes that incentives are set to 100% of incremental costs, noting that "the combination of this level of incentives along with well-designed programs with effective education and outreach would generally result in an overall measure penetration rate of 90 percent." Results in the study are disaggregated to show results for Vermont's two IOUs individually, but in table A6 below we focus on the statewide results. Through 2031, GDS estimates cumulative maximum achievable savings of 25.4% with an annual average of 1.3%. GDS estimates a portfolio cost effectiveness of 2.6 and net SCT benefits of almost $1.5 billion.

The study also reports results by sector and, although we do not share those results below, it is interesting to note that, unlike most studies, the highest savings potential exists in Vermont's residential sector by a fairly wide margin: 34.4% maximum achievable savings through 2031 versus 18.8% maximum achievable savings in the commercial/industrial sector.

Table A6. Overall results: Vermont (statewide), 2012–2031

Year	Analysis period (years)	Electric potential (% of sales)						SCT b/c ratio	SCT net benefits (million$)	Avoided costs* ($/kWh)
		Tech	Econ	Maximum achievable						
				Low	Med	High	average annual			
2011	20	32%	29%			25.4%	1.3%	2.6	$1,462	$0.175

* The components of avoided costs include avoided energy and capacity costs ($0.096 and $0.004 per kWh respectively), demand-reduction-induced price effects (DRIPE) for both energy and capacity ($0.043 and $0.003 per kWh respectively), and a $0.029/kWh adder for CO2 externalities. From R. Hornsby, P. Chernick, C. V. Swanson, D. E. White, I. Goodman, B. Grace, B. Biewald, C. James, B. Warfield, J. Gifford, and M. Chang, Avoided Energy Supply Costs in New England: 2009 Report, Cambridge, MA: Synapse Energy Economics, Inc., 2009 http://www.synapse-energy.com/Downloads/SynapseReport.2009-10.AESC.AESC-Study-2009.09-020.pdf (Hornsby et al. 2009).

Review of Methodologies and Assumptions

GDS' methodology for modeling customer adoption of energy-efficient measures (i.e., customer participation) is fairly standard: it is a simplified and concise method for estimating achievable potential savings that is common across the studies we reviewed. First, GDS assumes a maximum market penetration (adoption rate) of 80%–90%, depending on the type of equipment. The variation in market penetration is to account for increased barriers to measure adoption across end uses. After determining the number of cost-effective measures through the economic potential analysis, GDS applied one of four annual penetration curves (upward trending, bell curve, downward trending, and flat) to each measure, which was assigned based on cost and current market acceptance and designed to reach the 80%–90% maximum penetration by the end of the study time period.

GDS included emerging technologies in the analysis, but only provided information on residential ETs in the main body of the report. Residential ETs included: reverse cycle chillers for multifamily applications; direct feedback devices (in-home display units); indirect energy consumption feedback, and; solar water heaters. LEDs were included in

GDS' analysis but not as an ET, because Vermont's two EEUs have been providing rebates for LEDs for several years. Behavioral measures were included as ETs because of uncertainty about the persistence of their savings. The overall cost of ETs was reduced annually in light of several factors, such as increased market competition, reduced production costs, or technology maturation.

The avoided costs used in the study have been developed for the region and adopted by the Vermont Public Service Board. Synapse Energy Economics, Inc. prepared the analysis, which is updated regularly under the title *Avoided Energy Supply Costs in New England*. GDS' 2011 study for Vermont utilized the 2009 iteration for its avoided-cost assumptions (Hornsby et al. 2009). Although the value for avoided costs is not reported explicitly in the study, the Vermont Department of Public Service retains the study on its website.[32] The 2009 iteration breaks down the various components of the avoided-cost calculations, which includes avoided electric energy and capacity costs due to demand-reduction-induced price effects (DRIPE), avoided environmental externalities, and avoided T&D costs.

GDS points out in the study that utilities, customers, and society as a whole benefit from energy efficiency investments in ways other than by reducing energy and capacity costs, such as reductions in water consumption, emissions, reduced price volatility, and job creation. To account for these non-energy benefits, Vermont employs the Vermont Societal Test to evaluate the cost effectiveness of energy efficiency measures and programs. The test includes an environmental adder of $0.0070 per kWh saved (in 2000) and a 10% reduction of costs to account for "the risk diversification of energy efficiency measures and programs."

Observations

The State of Vermont has been a national leader in energy efficiency for decades and the assumptions and methodologies of GDS' study reflects Vermont's commitment. The study's inclusion of LEDs, ETs, and the incorporation of non-energy benefits into its evaluation of cost effectiveness as well in the calculation of avoided costs led to relatively high savings over the 20-year study period when compared to the other studies we reviewed with similar time periods. GDS utilizes a wide variety of recent, existing research from Vermont to inform its analyses and measure list development, so there was little, if any, need for primary data collection. Instead, GDS utilized a relatively simple, concise methodology to project important inputs such as customer adoption of energy efficient measures. In our interview with GDS, it was unclear the extent to which the study was integrated into the program planning process of all 21 utilities, who likely follow different plans. However, the detailed information provided on energy-efficient measure opportunities was likely useful to program planners.

Assessment of Energy and Capacity Savings in Iowa: The Cadmus Group, Inc.

We were unable to interview Cadmus about the Iowa study specifically because of open regulatory proceedings. Only in a few instances was Cadmus able to respond to questions about the Iowa study, so most of the comments they provided pertain to their general

[32] http://publicservice.vermont.gov/topics/energy_efficiency#potential_studies

methodology and perspectives outside the context of the Iowa study. Our discussion about the Iowa study specifically is predominantly informed by ACEEE's independent analysis.

Background

Cadmus' study for the Iowa Utility Association (IUA), published in 2012, was conducted to comply with rules established by the Iowa Utility Board (IUB) in 1990 and modified in 1996, which requires Iowa's three largest IOUs (that make up half of the IUA) to file energy efficiency potential studies every five years. The study considers both electricity and natural gas. The study builds upon primary data collection from the 2008 study, updating data based on program achievements and utilizing current customer and load forecasts; no primary data collection was done for the 2012 study. Informing program development is one goal of the study: the study provides a detailed discussion of net-to-gross within the context of specific program areas, in order to convey how free-ridership and spillover could impact savings potential for particular measures in particular programs.

Discussion of Overall Results

Cadmus conducts technical, economic, and market potential (maximum achievable) analyses for both electric and natural gas, considering only one market potential scenario where incentives are set up to 100% of incremental measure costs. Through 2023, Cadmus estimates a cumulative maximum achievable potential of 17.3% for electricity and 15.6% for natural gas, with average annual savings of 1.7% and 1.6%, respectively. Cadmus does not report the SCT ratio or net SCT benefits.

Cadmus notes in the report that these generous incentive levels would allow 91% of electric economic potential to be achievable, although that would require a more than twofold increase in budgets relative to actual 2010 statewide program expenditures, in part because of a correlating increase in non-incentive program expenditures. The conclusion that 91% of electric economic potential could be captured is the highest of any of the 45 studies we reviewed (only 24 studies provided enough data to perform this calculation): the average across studies was 61%.

Table A7. Overall results, electric and natural gas: Iowa, 2014–2023

Year	Analysis period (years)	Electric potential (% of sales)						SCT b/c ratio	SCT net benefits (million$)	Avoided costs ($/kWh)
		Tech	Econ	Maximum achievable						
				Low	Med	High	Average annual			
2012	10	24%	19%			17.3%	1.7%	NA	NA	NA
		Natural gas potential (% of sales)								
		35%	24%			15.6%	1.6%			

Review of Methodologies and Assumptions

Cadmus' approach to modeling participation is a common approach: the study focuses on "benchmarking," relying predominantly upon "historical market penetration achieved by a representative sample of relevant programs." The study does not elaborate on the methodology, but study authors at Cadmus noted that three generic adoption curves were applied to all measures—low (e.g., ETs), medium, and fast (maturing, such as CFLs)—depending on the market penetration of that measure. While accounting for the standard factors that influence customer participation, Cadmus also incorporates the impact of financing into its model. This is a unique exercise relative to our sample of studies, although it notes that financing availability to date has not had much success in driving customer participation. Cadmus further explains that in light of the performance of financing programs to date and the assumption that 91% of electric potential is achievable, it determined that it is unlikely that "availability of financing would increase market potential beyond that achievable assuming a 100% incentive."

Cadmus considers the potential for emerging technologies in the context of market potential (i.e., assuming incentives of 100% of incremental measure costs), for electricity only, defining ETs as those technologies that are expected to become commercially available and cost effective within the next five to ten years. Cadmus utilized a variety of resources to identify ETs for inclusion in the study, ultimately settling on eight measures—five residential and three commercial—that it estimates can contribute an additional 3% achievable electric savings. LEDs are assumed to be an ET in Cadmus' analysis, but were estimated to be cost effective only for the commercial sector as replacements for linear fluorescent lamps.

Codes and standards are taken into account at the measure level and with the base forecast, so that savings potential is assessed relative to a sales forecast with these savings removed. The study includes a detailed discussion on the issue of net-to-gross savings ("assessment of the net-to-gross ratio" in the study), to convey the potential impacts of free-ridership and spillover within the context of specific measures and programs. The conclusion of the assessment is that Iowa's utilities should use gross savings as the basis for reporting and target compliance, in part because most jurisdictions assume a NTG ratio of 1 at the portfolio level. Cadmus notes that "More than two-thirds of all evaluation studies reviewed in a recent best-practices study had a NTG value of approximately 1.0." So while codes and standards are "netted out" to provide a better picture of the potential impact of energy efficiency measures and programs, the savings potential reported is essentially gross savings: Cadmus does not account for free-riders or spillover, but, in its view, the two effects cancel each other out.

The Iowa Utility Board requires use of the Societal Cost Test when evaluating the cost effectiveness of energy efficiency measures and programs. In fact, Cadmus only evaluated cost effectiveness in the study using the SCT. Iowa's SCT requires an externality factor to be applied to avoided energy and capacity costs, in order to account for the societal costs of supplying energy. The externality factor adds an additional 10% to electric avoided energy and capacity benefits, and an additional 7.5% to natural gas energy and capacity benefits. Avoided line losses and other non-energy benefits (labeled "resources" in the Iowa study), such as water, are also included in Iowa's SCT. There is no mention of avoided transmission and distribution costs.

Observations

Cadmus' study for the Iowa Utility Association is a good example of a study that leverages existing research and data (i.e., forgoing primary data collection) in tandem with a sound methodological approach. Since the IUB requires potential studies to be conducted every five years, Cadmus was able to utilize primary data collection from the previous iteration and calibrate it using data from utility energy efficiency program experience. As a result, the data used in this study provide a thorough characterization of the current state of energy use in the three utilities' service territory. Capturing the impacts of ETs along with a more robust consideration of avoided costs provides a more robust picture of savings potential for the three IOUs. An additional 3% savings from ETs spread out over ten years works out to an additional 0.3% savings per year, which is hardly insignificant, particularly for utilities in states with annual savings targets. Cadmus' assessment of the net-to-gross ratio also provides some valuable information for utilities when designing their programs, recommending that, despite the assumption of an NTG ratio of 1.0, utilities need to remain diligent about monitoring measure saturation and using this information to revise their programs and incentive structures periodically.

The $20 Billion Bonanza: Best Practice Utility Energy Efficiency Programs and Their Benefits for the Southwest: The Southwest Energy Efficiency Project

We did not interview SWEEP for this case study. ACEEE was a contractor and lead analyst for the individual state program analyses, so our discussion below is based upon ACEEE's participation in the project.

Background

The Southwest Energy Efficiency Project (SWEEP) contracted with a number of organizations, including ACEEE, to complete its regional energy efficiency potential study, published in 2012. SWEEP's study seeks to make the policy case for energy efficiency, with a goal of developing a set of 18 best-practice utility energy efficiency programs based upon experience in the region and elsewhere in the country, and to estimate the potential savings and economic benefits that states in the Southwest could realize when implementing those programs. The study also reviews the policy and program framework affecting utility energy efficiency programs in each of the six states in the SWEEP region and recommends additional policies that would help to move each state toward best practice programs and their benefits.

Discussion of Overall Results

SWEEP did not conduct technical or economic potential analyses. Instead, it conducted individual program potential analyses for each of the six SWEEP states that built upon historical utility program performance within each state to inform costs, savings, and participation. SWEEP did not set incentives at any particular level for the program analysis: incentives within each program type were estimated per participant based on historical program performance. As a result, incentive levels varied by program, although no range is provided in the study. The study also includes savings realized in 2010 and 2011 through existing utility energy efficiency programs from the six SWEEP states.

The study reports results for each state individually, but table A8 below reports results for the entire Southwest region only. Through 2020, SWEEP estimates a cumulative maximum achievable potential of 21% and an average annual savings of 2.1%. Portfolio cost effectiveness is estimated using the TRC test, which SWEEP estimates at 2.14, with TRC net benefits of $20 billion for the entire region.

Table A8. Overall results: SWEEP region, 2010–2020

Year	Analysis period (years)	Electric potential (% of sales)						TRC B/c ratio	TRC net benefits (million$)	Avoided costs ($/kWh)
		Tech	Econ	Maximum achievable						
				Low	Med	High	Average annual			
2012	11					21%	1.9%	2.14	$20,000	NA

Review of Methodologies and Assumptions

SWEEP's study relied solely on secondary, publically available data to inform its analyses. Each state analysis includes a reference scenario for electricity sales and peak demand through 2020. The reference scenario excludes the impacts of all utility energy efficiency programs, even those programs underway or planned by utilities. The portfolio of model energy efficiency programs includes a comprehensive set of strategies for residential, commercial, and industrial customers based on best practice program offerings from leading utilities and other program administrators in the Southwest and elsewhere. The study includes savings realized in 2010 and 2011 through existing utility energy efficiency programs from the six SWEEP states, and assumes that existing programs are expanded after 2011.

For each program, SWEEP develops forecasts for the number of eligible customers statewide and then estimates participation rates based on historical program performance in the region and elsewhere. Projections of participation rates through 2020 build upon the historical participation rates, based on the judgment of the study authors as opposed to the application of technology adoption curves. In other words, participation is not estimated at the measure level, instead SWEEP leverages existing data from the region to inform participation over time. Reviewers of SWEEP's study opined that the participation rates appear optimistic, as some of the program analyses project a doubling or tripling of participation rates over ten years. While reviewers did not consider this to be unachievable, they suggested that it would take significant delivery efforts to meet the projected participation rates. SWEEP relies on existing, state/utility-specific potential studies or market assessments to determine end-use consumption by sector as well as measure saturation, where available, in order to ensure that participation and potential estimates from the individual programs do not surpass what is achievable.

Energy savings and peak demand impacts per participant are similarly estimated from best practice utility-specific programs as well as studies regarding different types of utility efficiency programs. Program and customer costs are estimated per participant or per first-year kWh saved, again based on specific programs in the region or best practice programs elsewhere in the country. SWEEP provides sources for these assumptions in Chapter 2 and Appendix A. Using the energy savings and cost estimates, SWEEP then analyzes the cost effectiveness of each program over the study time period. Estimates of gross program savings are based on a wide variety of sources from regional and national best practice programs. Net savings are calculated based on an assumed net-to-gross ratio for each program and were estimated based on typical program assumptions that are held constant across the six states.

SWEEP's methodologies for incorporating savings from codes and standards are common practice; however there is no explanation in the study of how this is accomplished. The statewide sales forecasts for each state are projected without adjusting for future building code adoptions in order to examine savings potential created exclusively by utility programs. This is equivalent to other studies' methodologies where embedded or naturally occurring energy efficiency is removed. Building codes are accounted for in the new construction program assessment for each state, where per participant savings and costs are adjusted for savings from expected code adoptions in the years those codes are effective. Although SWEEP does not conduct a technical or economic potential analysis, overall program potential is often estimated—depending on the program type—by multiplying annual projected participation by measure-specific per participant savings and costs. In cases where eligible program measures are subjected to federal equipment standards, SWEEP adjusts individual measure savings and costs based on the effective date of those standards.

While SWEEP does not explicitly mention the inclusion of emerging technologies in the study, the individual program analyses did include eligible technologies that are considered emerging. The lighting program assessments assumed that LEDs become eligible for rebates in 2012, which was based on the fact that several utilities in the Southwest region had been rebating LEDs for several years at the time of the study. SWEEP also considered a behavior/feedback program, which assumed the installation of in-home feedback monitors. Some of the studies we reviewed considered feedback measures to be emerging technologies.

Synapse Energy Economics, Inc. developed state-specific avoided costs for the SWEEP study. In light of time and budget constraints, and the policy nature of the study, Synapse developed and applied an electricity planning and costing model that produced high-level estimates of avoided costs for each of the six states. In its methodological discussion, SWEEP does not explicitly mention if Synapse's avoided-cost model incorporates factors to account for non-energy benefits, such as emissions reductions, nor does it report the actual avoided-cost values. However SWEEP provides a disaggregation of avoided costs for each state, in terms of total monetary value (million $, 2010), in a table providing benefit-cost results, showing assumed utility avoided costs in the study are comprised of: avoided capacity, T&D, pollution control, O&M, and fuel costs. No information is provided on the $/kWh value of the pollution control costs nor how these costs are developed.

Observations

SWEEP's study for the Southwest region is a good example of a potential study with a policy/program focus that aims to assess potential on a regional scale with a relatively small project budget. As a result, the study did not engage in primary data collection and utilized historical program experience, as opposed to models, to project customer participation and avoided costs. SWEEP utilizes extensive existing data from the region and elsewhere to inform and calibrate its models, so the study was developed upon a solid foundation of utility- and state-specific data. Reviewers, however, opined that the study's assumptions on participation rates over time were a bit optimistic, though not necessarily unachievable. The study does not include a discussion of how codes and standards are incorporated, and there is no discussion of emerging technologies, even though a few are included in its analysis. Greater transparency is warranted in these instances. However, the study examines state/regional savings potential within the context of existing best practice programs, so it is not exploring how future changes to programs or eligible measures could influence program savings potential: the study essentially extrapolates future energy savings based on current program best practices.

ComEd Energy Efficiency Potential Study Report: ICF International and Opinion Dynamics Corporation

Background

ComEd commissioned ICF International (ICF) and Opinion Dynamics Corporation to conduct this study, published in 2013, primarily to comply with the Illinois Public Utility Act, which requires utilities to file energy efficiency potential studies every 3 years, as well as to "gain insights for their program planning about additional energy efficiency savings that could be achieved in a maximum achievable potential scenario." The study focused on a six-year time horizon, befitting of its focus on program planning.

Discussion of Overall Results

ICF conducted analyses for three levels of potential: economic, maximum achievable, and program achievable. Its maximum achievable scenario was modeled assuming that incentives are set at 100% of incremental costs. Its program potential scenario was developed to estimate the amount of cost-effective potential that could be achieved given the statewide utility program budget cap of approximately 2% of annual customer's total electric costs. Incentives in this scenario were set to be consistent with existing program incentive levels, generally between 25% and 75% of incremental costs.

In light of the study's focus on program planning, ICF assigned measures to individual programs for the purposes of estimating achievable potential. The study included eight residential programs and ten commercial programs, while industrial measures were bundled by end use instead of by program. Each program represents a specific set of market interventions designed to increase the adoption of energy-efficient measures and, in most cases, the programs are modeled to be consistent with existing ComEd programs.

Through 2018, ICF estimates cumulative savings potential of 10% in the maximum achievable scenario and 6% in the program achievable scenario, or annual average savings of 1.7% and 1.0%, respectively. ICF estimates a TRC benefit/cost ratio of 2.2 for both the maximum achievable and program achievable scenarios, with TRC net benefits in the maximum achievable scenario of almost $2.4 billion.

TableA9. Overall results: ComEd, 2013–2018

Year	Analysis period (years)	Electric potential (% of sales)						TRC b/c ratio	TRC net benefits (million$)	Avoided costs ($/kWh)
		Tech	Econ	Maximum achievable*						
				Low	Med	High	Average annual			
2013	6			6.0%		10.0%	1.7%	2.2	$2,380	NA

*We report ICF's results for its maximum achievable analysis as the high scenario and we report its results for its program achievable potential analysis as the low" scenario.

Review of Methodologies and Assumptions

ICF's study is the only study of the ten we review in this section that conducted primary research to inform its participation model. ICF and ComEd collaborated to conduct ten "achievable potential workshops," whose purpose was to develop participation estimates for the various measures included in the analysis. ComEd and ICF program managers and planners attended each workshop, where they discussed and analyzed key measures representing each end-use, program, or sector. ICF does not elaborate in the study if stakeholders outside of ICF and ComEd were included in these discussions. Not all cost-effective measures were reviewed, so ICF selected "representative" measures to focus on, which were dependent upon if ICF considered that market's response to the measure could be generalized to similar measures. Achievable participation was estimated based on the workshop attendees' understanding of a particular measure, after discussing the various measure parameters, cost effectiveness, historical participation, barriers, and solutions to those barriers. Program and maximum achievable participation was estimated for 2013 and 2018, after which ICF presented various market penetration curves (linear, exponential, "S-curves," and growth-and-decline, as well as custom curves) to workshop attendees. The curves were discussed by attendees and were selected depending on which curve was believed to most likely represent the trajectory of the measure. Examples of how participation is estimated and incorporated for particular measures is provided in the study, but it does not provide quantitative data on the actual rates used in its model.

ICF accounts for codes and standards in its measure and program baselines and provides information on key baseline changes, such as lighting standards and Illinois' stringent building codes. It is uncertain the degree to which codes and standards impact savings potential; however, ICF does not provide any quantitative data on savings from codes and standards over the study time period. ICF includes residential and commercial new construction programs in its analysis, though their overall contribution to savings potential from new construction programs is relatively small. ICF focuses its discussion of federal standards on lighting, noting that CFLs and linear fluorescent retrofits account for the largest portion of historical savings from lighting in the residential and commercial sectors. ICF estimates that lighting will continue to play a large role in ComEd's residential and commercial program portfolios: savings from lighting through 2018 are estimated at 43% and 60% of total maximum achievable potential, respectively.

ICF does not include emerging technologies in the study. There is no mention of ETs in the main body of the study, but, given the short time period of the study, this is understandable. ICF identified measures using Illinois' Technical Reference Manual plus additional measures included in a recent gap analysis. ICF notes that measure selections were limited to those that are "commercially available," which includes LEDs: ComEd has program experience with LED rebates. Although ETs were not necessarily considered, ICF did include measures that are not cost effective in the achievable potential analysis, which are predominantly LEDs and residential central air conditioners (CAC). ICF notes that despite CACs not being cost effective as a standalone measure, they can become cost effective when bundled with other measures, such as with an efficient gas furnace in a "complete system replacement."

ComEd supplied the avoided cost assumptions for the study. ICF does not provide additional information on the avoided-cost calculations beyond that they were updated by ComEd in June 2013. The TRC test is the basis for cost-effectiveness calculations at the measure and program level, but there is little information about what is included in these calculations, such as avoided T&D costs or non-energy benefits.

Observations

ICF's study for ComEd is a good example of a potential study that successfully combines primary and secondary research to help inform utility program development. ICF's study is one of the few of the 45 studies that incorporate detailed discussions about savings potential results into discussion of program design. Additional transparency and elaboration upon its assumptions on avoided costs, at the very least the various components that are included in the calculations, would be helpful to readers. The discussion of the treatment of codes and standards is useful, but more information on the magnitude of expected savings impacts would also be helpful, particularly since savings potential from lighting through 2018 is estimated to be significant relative to overall savings potential.

Appendix B: Detailed Quantitative Results

Table B1. Overall results: technical, economic, and achievable savings potential, electric only

State/utility	Electric savings potential					Maximum achievable savings as % of ec. potential	Average annual maximum achievable savings (%)	Utility avoided costs ($/kWh)*
	Tech	Econ	Achievable					
			Low	Med	High			
Studies with analysis period of 16–20+ years								
Eastern US					31.5%		1.5%	
Idaho Power	37.4%	22.8%			12.2%	53.5%	0.6%	$0.029- $0.053
Kansas City P&L				22.5%	29.2%		1.5%	
LG&E/KU (KY)	22%	10%	3.9%	5.7%	6.1%	61.0%	0.3%	
Puget Sound	22%				16.0%		0.8%	
PacifiCorp	15%				12.0%		0.6%	
Avista (WA & ID)	56.0%	34.3%			17.6%	51.3%	0.9%	$0.045- $0.049
Louisiana					16.0%		0.9%	
Entergy NO			8.5%	12.2%	17.2%		0.9%	$0.036- $0.077
Kentucky					19.1%		1.1%	
AEP OH	38%	29%		19%	22.0%	75.9%	1.1%	
Vermont	31.7%	29.2%			25.4%	87.0%	1.3%	
PacifiCorp	19%				16.0%		0.8%	
TN Valley Auth.	31.6%	24.8%	10.6%		19.8%	79.8%	1.0%	
New Mexico	20%	14.7%	6.2%		11.1%	75.5%	0.7%	$0.0395- $0.0724
Arkansas		15%		15.0%	22%	146.7%	1.4%	
North Carolina				24%	32%		2.0%	
NPC/SPPC (NV)	43.4%	31.1%			15.6%	50.2%	0.8%	$0.062- $0.0716
Pennsylvania		33%			22.7%	68.8%	1.3%	
Ohio		33%			23.4%	70.9%	1.3%	
South Carolina				20.5%	27.6%		1.7%	

State/utility	Electric savings potential					Maximum achievable savings as % of ec. potential	Average annual maximum achievable savings (%)	Utility avoided costs ($/kWh)*
	Tech	Econ	Achievable					
			Low	Med	High			
Studies with analysis period of 10–15 years								
Washington DC	44.7%	43.0%	18.2%	21.1%	29.4%	68.4%	2.9%	
Michigan	38.4%	30.1%	5.7%	13.5%	15.0%	49.8%	1.5%	
California			7.9%	11.7%			1.0%	
Ameren (MO)	29.2%	22.9%		11.7%	15.9%	69.4%	1.1%	$0.032- $0.047
Mississippi					12.8%		1.3%	
Georgia Power			6.1%	9.3%	15.3%		1.3%	
Iowa Util. Assoc.	24%	19%			17.3%	91.0%	1.7%	
FirstEnergy OH	33%	27%		12.7%	16.8%	61.8%	1.3%	
Southwest					21.0%		1.9%	
Pennsylvania	32.6%	27.2%		7.9%	17.3%	63.6%	1.7%	$0.0457- $0.0861
Missouri				10.1%	17.3%		1.2%	
Xcel CO 2010		23%	6.4%	10.1%	17.5%	76.0%	1.6%	$0.06- $0.085
Wisconsin		18%		13%	16%	88.9%	1.6%	$0.037- $0.074
Studies with analysis period of 1–9 years								
ComEd (IL)		32%	6.0%		10.0%	31.3%	1.7%	
Xcel CO 2013	33%	23%			12.1%	52.7%	1.5%	$0.0465- $0.0897
Indiana P&L	13.8%	10.2%	2.5%		5.2%	51.0%	1.3%	
New Jersey	13.5%	12.8%	3.1%		5.9%	46.1%	1.5%	$0.0503- $0.0944
ConEd (NY)					9.0%		1.0%	
Duke Ohio	29%	13%			3.10%	23.8%	0.6%	$0.06
Duke Kentucky	31%	15%			3.40%	22.7%	0.7%	$0.06

* Avoided costs for Idaho Power are estimated from figure 2-4, representing projections for 2011–2032 (EnerNOC 2013c). For Avista, avoided costs are estimated from figure 2-4, representing projections for 2010–2033 (EnerNOC 2013a). For Entergy NO, avoided costs are from Appendix C, representing projections for 2011-2031 (ICF 2012). For New Mexico, avoided costs are a statewide

average from table 2-13, representing projections for 2009-2025 (GEP 2011a). For NPC/SPPC (Nevada), avoided costs are from table 4-2 for NPC's and SPPC's residential sector in 2009 (PA Consulting Group 2009). For Ameren (MO), avoided costs are estimated from figure 7-1, representing projections for 2011–2033 (EnerNOC 2013b). For Pennsylvania, avoided costs are summer peak values for PECO representing projections for 2012–2026 (GDS 2012). For Xcel CO 2010, avoided costs are estimated from figure 3-4, representing summer (and winter) peak values for 2010–2020 (KEMA 2010). For Wisconsin, avoided costs are from table EE-4, representing summer off-peak and on-peak, respectively, for 2008; no forecast provided (ECW 2009). For Xcel 2013, avoided costs are from Appendix A, representing projections for 2013–2032 (KEMA 2013). For New Jersey, avoided costs are from Appendix G, table G-1, representing projections for 2010–2033 (EnerNOC 2012b). For Duke Ohio and Kentucky, the study only reported one value for avoided costs and offered no projections (Forefront and Peach 2009a and 2009b).

Table B2. Overall results: technical, economic, and achievable savings potential, natural gas only

State/utility	Natural gas savings potential					Maximum achievable savings as % of ec. potential	Average annual maximum achievable savings (%)	Utility avoided costs ($/therm)
	Tech.	Econ.	Achievable					
			Low	Med	High			
Studies with analysis period of 16–20+ years								
LG&E/KU (KY)	33.0%	16.0%	5%	8%	9.0%	56.3%	0.5%	
Puget Sound	32.0%				21.0%		1.1%	$0.953
Louisiana					12.0%		0.7%	
Kentucky					24.5%		1.4%	
Entergy NO								$0.398- $0.591
Vermont								$1.00
New Mexico								$0.707- $0.920
Arkansas		44.0%		14.0%	16%	36.4%	1.0%	
Pennsylvania		27%		15%		0.0%	0.8%	
Studies with analysis period of 10–15 years								
CenterPoint MN							2.2%	
Washington DC	34.5%	30.8%	10.4%	12.5%	24.1%	78.2%	2.4%	
Michigan	37.9%	20.4%	5.70%	10.6%	13.4%	65.7%	1.3%	
California								
Mississippi					9.8%		1.0%	
Iowa Util. Assoc.	35%	24%			15.6%	65.0%	1.6%	

State/utility	Natural gas savings potential					Maximum achievable savings as % of ec. potential	Average annual maximum achievable savings (%)	Utility avoided costs ($/therm)
	Tech.	Econ.	Achievable					
			Low	Med	High			
Missouri				7%	13.0%		0.9%	
Wisconsin		16%		8.70%	11%	68.8%	1.1%	$0.84
Minnesota	36%	20%						
Studies with analysis period of 1–9 years								
North Shore Gas (IL)	41.0%	24.0%	1.2%		2.4%	10.0%	0.8%	$0.37- $0.63
Peoples' Gas L&C (IL)			0.9%		1.5%		0.5%	$0.37- $0.63
New Jersey	14.1%	4.5%	0.90%		1.8%	40.0%	0.5%	$0.447- $1.019
ConEd (NY)					6.0%		0.7%	
Duke Ohio	29%	21%			0.70%	3.3%	0.1%	$0.90
Duke Kentucky	29%	20%			1.00%	5.0%	0.2%	$0.90

* Avoided costs for Puget Sound are from table C-1, reported in decatherms (Haeri et al. 2013). For Entergy NO, avoided costs are from Appendix C and represent projections for 2011–2031 (ICF 2012). For Vermont, avoided costs are for 2009, reported in decatherms, and are taken from the report *Avoided Energy Supply Costs in New England* (Hornsby et al. 2009). For New Mexico, avoided costs are from table 2013, representing projections at the statewide level for 2009–2015 (GEP 2011a). For Wisconsin, avoided costs are from table EE-4 and represent values for 2008, both summer and winter on- and off-peak (ECW 2009). For North Shore Gas and People's Gas L&C, avoided costs represent base and high case values, but the year is undefined (Kihm 2013a and 2013b). For New Jersey, avoided costs are from Appendix G, table G-1, representing projections for 2010–2033 (EnerNOC 2012b). For Duke Ohio and Kentucky, avoided costs are reported in the text and a year is not defined (Forefront and Peach 2009a and 2009b).

Table B3. Overall results: benefit/cost results and average annual maximum achievable savings potential, electricity only

State/utility	Average annual maximum achievable savings (%)	Benefit/cost results					TRC benefits (million$)	TRC costs (million$)	TRC net benefits (million$)
		RIM	UCT	TRC	PCT	SCT			
Studies with analysis period of 16–20+ years									
Kansas City P&L	1.5%	0.7	3.1	1.9	3.2	2.5			
Louisiana	0.9%		3.4	1.8	3.5		$9,502	$5,219	$4,282
Entergy NO	0.9%	0.6	2.5	1.9	5.5				
AEP OH	1.1%	0.5	2.9	1.7	4.2				
Vermont*	1.3%					2.6	$2,404	$942	$1,462
TN Valley Auth.	1.0%	0.76	2.56	1.5			$21,924	$16,511	$5,413
Arkansas**	1.4%			2.5	3		$4,234	$1,711	$2,523
North Carolina**	2.0%			2	2.9		$19,353	$9,593	$9,760
Pennsylvania	1.3%			1.8	2.4		$16,580	$9,280	$7,310
Ohio	1.3%			1.7	2.6		$12,528	$7,214	$5,314
South Carolina**	1.7%			1.4	1.8		$5,925	$4,342	$1,583
Studies with analysis period of 10–15 years									
Washington DC*	2.9%					6.95	$12,670	$2,541	
Michigan	1.5%		2.73	2.71			$16,434	$6,063	
California	1.0%								
Ameren (MO)	1.1%	0.54	1.65	1.24	6.23		$2,718	$2,190	
Mississippi	1.3%		4.5	2.5	4.3		$3,730	$1,479	$2,251
Georgia Power	1.3%	0.6		2.4	4.8				$5,733
FirstEnergy OH	1.3%		2.1	1.2	5.5				
Southwest	1.9%			2.14			$37,155	$27,421	$19,801

State/utility	Average annual maximum achievable savings (%)	Benefit/cost results					TRC benefits (million$)	TRC costs (million$)	TRC net benefits (million$)
		RIM	UCT	TRC	PCT	SCT			
Pennsylvania	1.7%			1.95			$21,027	$10,759	$10,268
Missouri	1.2%		2.1	1.4	3.1		$5,339	$3,871	$1,469
Xcel Colorado	1.6%			2.8			$6,496	$2,331	$4,166
Studies with analysis period of 1–9 years									
ComEd (IL)	1.7%			2.2			$4,310	$1,930	$2,380
Xcel CO	1.5%			2.5			$4,411	$1,773	$2,639
Indiana P&L	1.3%	0.59	2.23	1.3	3.89		$249	$192	$57
Duke Ohio	0.6%			2.3					
Duke Kentucky	0.7%			1.9					

All benefit/cost monetary values represent TRC benefits and costs unless otherwise specified. * Benefits and costs for Vermont and Washington, DC are for the Societal Cost Test (SCT). ** Values represent those for the medium-case scenario in the study.

Appendix C: Lighting Potential

Table C1. Technical, economic, and maximum achievable lighting potential, percent of total maximum achievable savings potential

Jurisdiction	Study period	Year for result	Tech			Econ			Maximum achievable		
			Res.	Comm.	Ind.	Res.	Comm.	Ind.	Res.	Comm.	Ind.
Studies with analysis period of 16–20+ years											
Idaho Power	21	2017							59%	46%	11%
KCP&L	20	2033							28%-30%		
LG&E/KU (KY)	20	2033				4%	24%				
Puget Sound	20	2033							11%	40%	8%
PacifiCorp	20	2032							8%	37%	20%
Avista (WA & ID)	20	2018							47%	57%	
Entergy NO	20	2018				49%	68%	7%	40%	60%	8%
AEP OH	20	2031							39%	57%	
VT	20	2031							15%	48%	
PacifiCorp	20	2030							8%	46%	11%
TN Valley Auth.	20	2030							12%	34%	9%
NM	16	2025							36%	49%	<1%
Studies with analysis period of 10–15 years											
Washington DC	10	2022	27%	41%		28%	40%		31%	40%	
MI	10	2023	33%	43%	18%	33%	38%	18%	29%	37%	21%
Ameren (MO)	15	2025							13%	46%	41%
Georgia Power	10	2023							11%	50%	12%
Iowa Util. Assoc.	10	2023				21%	62%	24%			
PA	10	2023	28%	40%		32%	39%		19%	41%	
Xcel CO 2010	11	2020	23%	49%	16%	26%	47%	17%	24%	57%	26%
Studies with analysis period of 1–9 years											
IL/ComEd	6	2018				49%	68%	7%	43%	60%	6%

Jurisdiction	Study period	Year for result	Tech			Econ			Maximum achievable		
			Res.	Comm.	Ind.	Res.	Comm.	Ind.	Res.	Comm.	Ind.
Xcel CO 2013	8	2020	26%	58%	16%	30%	44%	17%	27%	55%	30%
IN P&L	4	2017	44%	32%	26%	51%	40%	26%	46%	37%	27%
NJ	4	2016	83%	44%	17%	64%	46%	17%	77%	58%	18%
ConEd NY	9	2018							45%	63%	

Appendix D: Interview Questions

1. Who commissioned the study and why?
    a. If for resource planning or target-setting purposes, how was the study envisioned to inform the process?
    b. If for program planning purposes, what role did the study have in influencing portfolio development?
    c. To what extent were stakeholders engaged throughout the process? Was public participation encouraged? If so, were any aspects of the study considered proprietary?

2. What levels of EE potential are analyzed?
    a. How does the study define and analyze achievable potential?
    b. If there are multiple scenarios for a certain potential level (e.g., achievable), what were the assumptions for each scenario?

3. What assumptions are made about the underlying limitations for EE potential, such as policy drivers or economic factors?
    a. Budget/spending limits; savings targets/requirements; incentive levels; payback periods.
    b. How were these factors modeled into the analysis?
        i. What are the assumptions? Sources?
    c. Are the limitations self-imposed or driven by regulations or stakeholder input?

4. How did the study forecast utility sales?
    a. Did the study remove embedded EE from the forecast so that the baseline forecast assumes no EE investments in the future?

5. How did the study estimate customer participation rates?
    a. Did the study account for free-riders as well as free-drivers and spillover? If not, why?
    b. Did these rates vary over time and how?
    c. Was there discussion about the role behavior/feedback programs can play in increasing participation in other utility programs?

6. Did the study estimate savings as net or gross?
    a. What was the rationale?
    b. Do these assumptions align with current practices (IRP)?

7. Which cost-effectiveness tests were used to determine EE potential?
    a. How were cost-effectiveness tests applied? To measures only? To programs and/or portfolios?
    b. If at the measure-level only, were measures bundled in some way?
    c. If the TRC or societal test was used, what were the assumptions for NEBs?
    d. What were the assumptions for discount rates? Did these vary over time?

8. How does the study account for savings from building energy codes and federal/state appliance standards?
   - **a.** Is there an estimate of the percentage reduction in forecasted sales arising from codes and standards?
   - **b.** Were equipment standards incorporated into potential savings by measure, over time?
   - **c.** What sources were used to determine these estimates?

9. How many end-use measures were included in the analysis, by sector (assuming bottom-up analysis)?
   - **a.** What sources were used to determine measure savings?
   - **b.** What sources/assumptions were used to estimate measure penetration?
   - **c.** Were emerging technologies included?

10. What were the assumptions for natural gas prices?
   - **a.** What sources were used to forecast NG prices?
   - **b.** Is there an estimate of the impact of varying levels of NG prices on EE potential?

11. What were the assumptions for avoided costs?
   - **a.** Are the avoided-cost assumptions utility specific or based on other values?
   - **b.** Were ACs assumed to vary over time relative to energy prices?
   - **c.** Did ACs vary across scenarios?
   - **d.** Did the study include avoided costs other than energy and capacity?

12. To what extent was the study used for program planning?
   - **a.** Did the study make programmatic recommendations for capturing the identified potential?
   - **b.** If so, was there discussion about best-practice program design and its ability to influence participation levels (beyond simply raising/lowering incentives)? For example, marketing or retrocommissioning programs?

13. What have been the biggest trends and changes in EE potential studies over the past five years?
   - **a.** Are they shifting more toward a programmatic focus, or at least including discussions on related hurdles?
   - **b.** Are they becoming more or less integrated into statewide energy planning processes?
   - **c.** Are they considered a tool for understanding economic growth potential obs, GSP, etc.)

14. What changes do you anticipate to your approach(es) in the future? Why?