Energy Efficiency Over Time: Measuring and Valuing Lifetime Energy Savings in Policy and Planning

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Executive Summary

KEY TAKEAWAYS

- Utility-sector energy efficiency programs have traditionally focused more on achieving and reporting first-year energy savings than on the expected savings over a measure's lifetime.
- Programs and policies, including energy efficiency resource standards, performance incentives, and cost-effectiveness testing, should give more attention to efficiency's long-term value, not only to optimize portfolio management and resource planning but also to encourage more long-lived measures and savings and so increase the benefits of energy efficiency.
- A growing number of states show a preference for energy efficiency portfolios that deliver longer-term savings and for policies that recognize efficiency's value for resource planning and climate policy over time. Preliminary results suggest that these policies are effective.
- Researchers in leading states are starting to gather better data to improve measure lifetime estimates; more states should continue this research.

The duration of energy efficiency measures and savings ranges from a few months for air-conditioning filter replacement to 40 years or more for some efficient design and construction measures in new buildings. However utility-sector energy efficiency programs have traditionally focused much more on achieving and reporting first-year energy savings than on the expected savings over a measure's lifetime. They have placed much less emphasis on energy savings over time and whether the measures put in place continue to deliver value to customers and the system in future years. This is largely because state policies like energy efficiency resource standards (EERSs) typically focus on first-year rather than lifetime savings. It is also to some extent a practical result of the fact that it is much easier to evaluate and report first-year savings impacts.

In spite of these factors, there is growing recognition that policies and programs should give more attention to efficiency's long-term value. Doing so will not only improve portfolio management and resource planning but also better facilitate the use of energy efficiency as a long-lived resource. Accomplishing this will increase the benefits of energy efficiency to utility systems and to society.

SHORT-TERM VERSUS LONG-TERM MEASURES AND ENERGY SAVINGS

This report draws on a literature review and interviews with utility personnel, resource planners, and evaluators. We find that although average measure lives vary across utilities, many portfolios rely heavily on short-term measures. Portfolios should balance these with long-term measures, as both have their advantages. Those with shorter lifetimes can be easy to ramp up quickly, simple to implement, and cost effective for meeting first-year savings goals. Long-lived measures, in contrast, offer persisting value over time, essential for resource planning and long-term deferral or displacement of supply-side resources. Some long-lived measures may better support nonenergy benefits such as increased health, safety, and property value.

ESTIMATING MEASURE LIFETIMES

A measure's effective useful life (EUL) combines its technical life (e.g., the number of years a piece of equipment will function) and the persistence or change in savings over time. Although EUL estimates are critical to portfolio planning and investment, they vary dramatically, and actual studies of EUL are uncommon. The best sources use careful, up-to-date primary research rather than relying on proxies. They are vetted by independent third parties and assess the multiple factors that influence measure life. Evaluators and utilities in Ontario, Illinois, and California have begun to rigorously assess effective useful life estimates in their research. We recommend that other states continue this effort. We also recommend that states focus on the most critical variables, leverage other jurisdictions' research, and concentrate on high-impact measures and those for which a deficient EUL is associated with a high level of risk. Measures that may require attention include those that have very short or long lives; dual baselines; or operational, control, or behavioral components.

APPLICATIONS OF LIFETIME SAVINGS ESTIMATES

Lifetime savings estimates have four primary applications in state energy policy:

- Cost effectiveness
- Energy efficiency goals in EERSs
- Performance incentives
- Resource planning

Programs rely on estimates of measure lifetimes to calculate their cost effectiveness and help determine which efficiency investments to make. Used as an input to cost-effectiveness screening, lifetimes enable planners, program administrators, and policymakers to decide among energy efficiency measures in portfolio planning and to develop savings targets.

Of the 27 states with an EERS, 25 currently focus on first-year or incremental annual savings. By not accounting for savings over time, first-year goals alone tend to emphasize measures with low first-year costs and high initial cost effectiveness. In contrast, states may set goals involving measures of longer-term savings. These goals are sometimes called *cumulative* or *lifetime*, and we have found a range of approaches, including total annual savings (used in Illinois electric programs), portfolio measure minimums (used in Illinois gas programs), projected savings (used in Ontario), and program-cycle savings (used in Wisconsin). Although there is some early evidence that these changes may support longer lifetimes and better alignment with resource planning, the magnitude of their impact is largely unknown.

Performance incentives can encourage investment in longer-term measures by tying eligibility and awards to savings over time. Explicit lifetime incentives are awarded on the basis of performance against total annual or projected savings targets. In Michigan and Ontario, these are correlated with achievement of lifetime targets and increases in portfolio average measure life. Illinois's recent change to explicit incentives suggests a similar pattern.

Resource planning should fully take into account the value of efficiency savings over measure lifetimes. We recommend that states carefully consider savings lifetimes when evaluating program impacts, including savings persistence and decay. They should also account for complex baselines and energy savings performance at measures' end of useful life.

RECOMMENDATIONS

Program Administrators

- Track lifetime and annual savings, including the roles of persistence, shifting baselines, and end-of-measure-life performance.
- Deliver long-term savings through new and enhanced program offerings.
- Review the current state of EUL practice, update measure lifetimes, and prioritize measures and programs for research.

Policymakers

- Review and modify goals, performance incentives, and policy guidance as needed to ensure that programs value the persisting savings from installed measures.
- In cost-effectiveness testing and potential studies, use discount rates and avoided-cost assumptions that maximize the value of energy efficiency over time.
- Clarify assumptions used in policy decisions about baselines, decay, and end of measure life.
- Promote transparent planning processes that include energy efficiency as a resource and value efficiency measures for their full lifetime.

CONCLUSIONS

States should place greater emphasis on the lifetime of energy efficiency resources. Robust cost-effectiveness testing, performance incentives, and resource planning may support a portfolio that balances short- and long-term savings alongside other policy priorities like equity and bill impacts. However a further shift toward policies that promote lifetime savings will help capture the full, lasting value of energy efficiency. The recent attention to lifetime savings goals and performance incentives in a few leading states is an encouraging development that will provide important information and insight as we observe the implementation of policy innovations.

Introduction

Energy efficiency measures reduce energy use while delivering the same or better level of services. Efficiency reduces customer bills, lowers utility system costs, and provides numerous health, comfort, climate, and resilience benefits. Measures vary in the duration of their use (their lifetime) and their potential energy savings. Lifetimes and savings range from a few months for air-conditioning filter replacement to 40 years or more for some building envelope measures. Savings may be consistent over time, or they may vary seasonally or over the lifetime of the measure. Figure 1 represents the typical lifetime of savings from various measures installed or implemented in 2020.

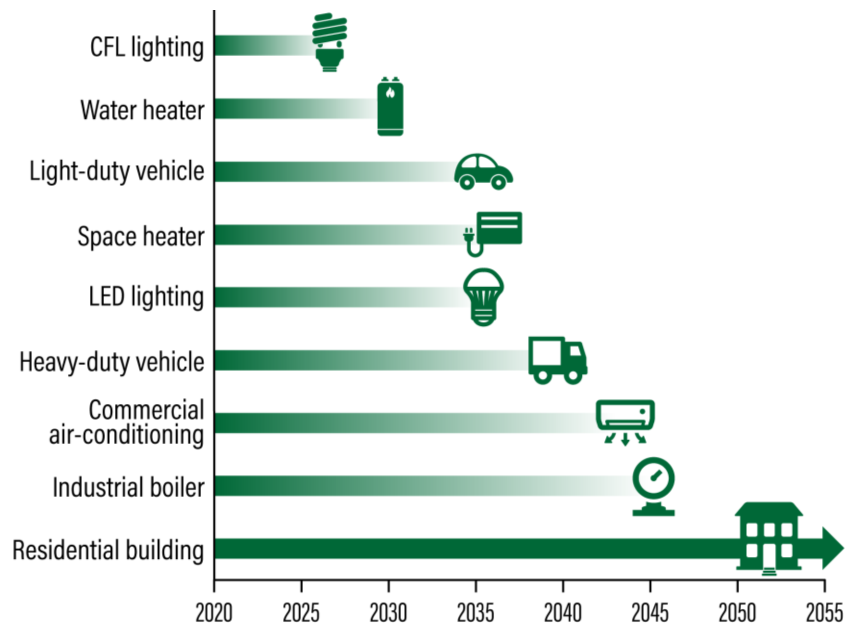

Figure 1. Various lifetimes of energy investments

Utility-sector energy efficiency programs have traditionally focused on achieving and reporting first-year energy savings as opposed to lifetime energy savings—i.e., the expected savings over the lifetime of a given measure. Much less emphasis has been placed on energy savings over time and whether the measures put in place continue to deliver value to customers and the system in future years. This is largely because state policies tend to focus on first-year savings rather than the lifetime of efficiency measures. For example, most energy efficiency resource standards (EERSs) set targets for first-year energy savings and assess and track those savings.[1] Lifetime savings are an input in cost-effectiveness analysis and energy efficiency potential studies, which program administrators use to screen eligible

[1] An EERS sets a binding, long-term (three or more years) energy savings target for a utility or third-party program administrator. Savings are achieved through efficiency programs for customers.

measures based on their costs and benefits. However most program administrators are motivated primarily by their savings goals and any performance incentives.[2]

This relative lack of focus on lifetime energy savings in EERS policies is a growing concern. If energy efficiency is regarded as a utility system resource, then policies that consider the value of energy efficiency over time are critical to portfolio management and resource planning. More attention to lifetime savings could also encourage more long-lived energy savings measures and so increase the benefits of energy efficiency.

Some policymakers in various parts of North America are testing new policy mechanisms that increase focus on lifetime energy savings in setting goals and incentives. In 2012 Ontario's regulators restructured their gas energy efficiency programs and incentives around lifetime rather than first-year savings (OEB 2011a). Similarly, in 2016 Illinois passed the Future Energy Jobs Act, which changed its electricity energy efficiency program goals and shareholder incentives from first-year to cumulative annual persisting savings, a type of lifetime savings (Illinois General Assembly 2016).

Report Methodology and Structure

This report is aimed at three primary audiences: program administrators, policymakers, and evaluators.[3] Its goal is to help these stakeholders realign planning; policy; and evaluation, measurement, and verification (EM&V) in a way that values energy efficiency over its lifetime. A first step is to understand how current practices and policies encourage measures that perform well in achieving first-year goals. The alternative involves considering and measuring the value of energy efficiency over its lifetime. We explore emerging strategies to align this value with policies, planning, and measurement. We also describe the benefits and challenges associated with transitioning policy regimes to lifetime savings or adding policy components that focus on them.

We began this study by conducting a literature review and interviews with evaluators, resource planners, and utility personnel. In each conversation, we aimed to understand the current state of practice for energy efficiency goals, shareholder incentives, resource planning, and lifetime savings estimates.

Through this research, we identified five promising jurisdictions for further study: California, Illinois, Michigan, Ontario, and Oregon. Then we developed case studies for each jurisdiction by reviewing regulatory filings and interviewing utility personnel, regulators, evaluators, and in some cases separate resource-planning entities. We built on

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[2] Cost-effectiveness screening, which incorporates value over a list of measures, is used to set goals in some states. However this analysis is nearly always used to establish a floor for what measures and programs are acceptable. Typically, far more measures and programs will pass than there are budget and other capabilities to implement, so program administrators have discretion in choosing the portfolio. Those choices are usually oriented to facilitate reaching savings goals or earning available incentives.

[3] Program administrators manage energy efficiency portfolios and often conduct resource planning. Policymakers create an environment to support efficiency investment, and evaluators analyze its success.

lessons learned from cases to suggest recommended practices for states, utilities, and evaluators considering the role of lifetime savings in their efficiency policy and programs.

Our report expands on research on lifetime savings in evaluation by Skumatz Economic Research Associates (SERA), Lawrence Berkeley National Laboratory, and Navigant (Skumatz 2012b, 2011; Hoffman et al. 2015; Navigant 2018). We build on the work of advocates and analysts in Ontario, Illinois, and Michigan on policy options for lifetime savings, particularly Neme (2018) and Optimal Energy (2013). These sources provide a set of theoretical options for lifetime-based goals and performance incentives.

The report is organized as follows. First we highlight the different values that short- and long-term measures bring to policy efforts, and we outline the challenges for resource planning in having first-year goals and incentives that do not align with the value of efficiency over time. Then we define key lifetime savings concepts. This is followed by a discussion of the available sources for estimating lifetime savings, the issues surrounding these estimates, and recommendations of ways for states to improve them. We then describe typical and emerging approaches to applying lifetime savings in EERSs, utility performance incentives, and resource planning, and we explore the benefits and downsides of those strategies. We conclude with recommendations for program administrators, policymakers, and evaluators who influence how efficiency is valued over its lifetime. Appendix C contains case studies of state efforts to address lifetime energy savings in their policy and EM&V.

Short-Term versus Long-Term Measures and Energy Savings

Those making energy efficiency investments should consider both long-term resource needs, in order to value efficiency as a replacement for traditional infrastructure, and short-term needs, in order to address near-term capacity or distribution requirements. Planning horizons vary by jurisdiction, but we generally view measure lives as short term when they are briefer than a typical utility planning horizon (~10 years), especially so when they are shorter than an energy efficiency planning cycle (often 2–5 years).

Portfolio average measure lives vary across utilities, with some relying more than others on short-term measures to meet their savings goals. Among the most common short-term measures are operational measures (e.g., retrocommissioning, compressed air lead repair, boiler tune-ups), some control and energy management measures, behavioral programs, and residential lighting.[4] ACEEE's *2017 Utility Energy Efficiency Scorecard* included measure life data for 41 of the 51 top electric utilities in the country (figure 2). These utilities had average portfolio measure lives ranging from 3.7 years (Georgia Power) to 20.4 years (Pacific Gas & Electric), with an average of 11.1 years across all 39 utilities (Relf, Baatz, and Nowak 2017). Average measure lives have generally not shifted in recent years; a 2014 survey found

[4] These types of measures had the shortest lives (less than five years) in a review of the Michigan Energy Measures Database and are consistent with our review of other technical reference manuals.

an average life across the country of 11 years, with 8 years for residential and 13 years for business programs (Molina 2014).[5]

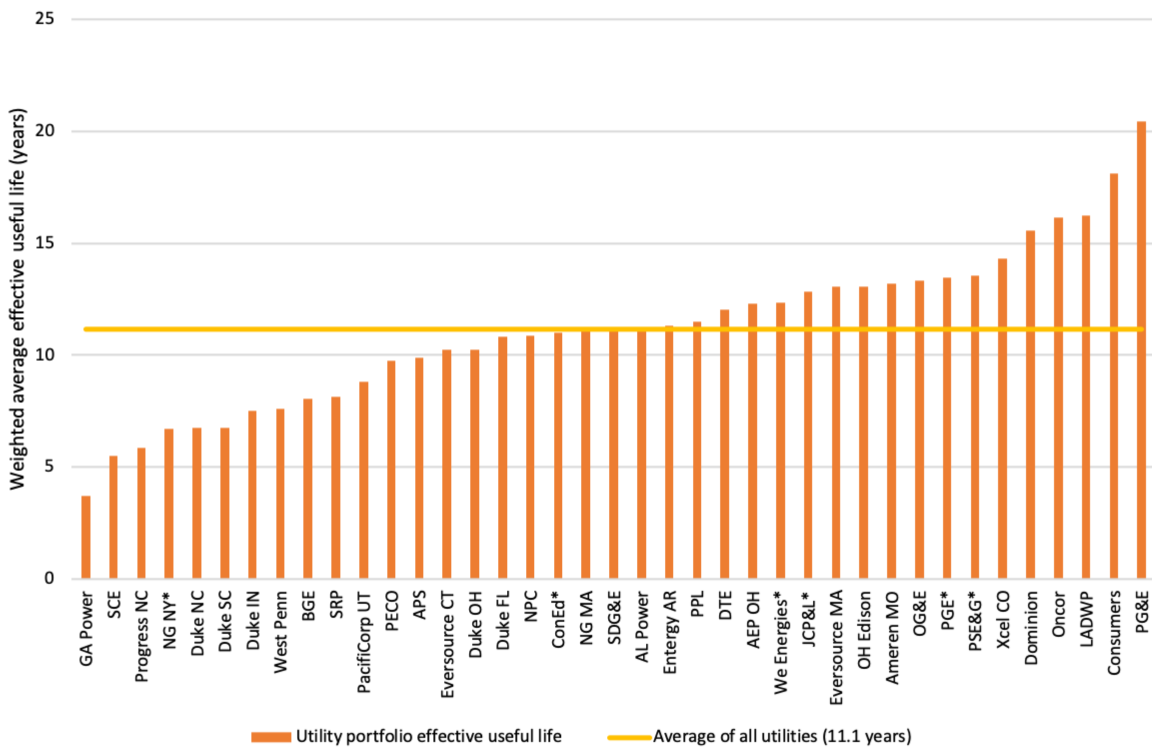

Figure 2. Portfolio average measure life as reported in Relf, Baatz, and Nowak (2017). Utilities with an asterisk (*) include savings from a third-party administrator. PG&E and SDG&E count codes and standards support, which increases their measure life. Methodologies for calculating measure lives for technologies and programs vary across utilities. Relf et al. relied on annual reports or other filings for either lifetime savings or a weighted average useful life for the total portfolio and followed up with utility contacts where those data were unavailable.

The distribution of measure lives in figure 2 suggests that many portfolios rely on short-term measures. In fact, a recent analysis of the cost of saved energy across Lawrence Berkeley National Laboratory's Demand-Side Management (LBNL DSM) Program Database found that lighting programs, which are often short- or medium-term measures, accounted for 45% of the residential sector's lifetime savings.[6] Baatz, Gilleo, and Barigye (2016) profiled program administrators saving more than 1.5% of retail sales.[7] Where there were data breaking down the types of measures, Baatz and his coauthors found that residential

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[5] The lack of change could reflect minimal adjustments to programs over that time, limited revisions of effective useful life estimates, or limited technological change and innovation.

[6] This database is built on annual reports filed by program administrators of electricity efficiency programs in 41 states from 2009 to 2015. The data set includes both annual and lifetime gross and net energy savings for electricity efficiency programs as reported by 116 program administrators (Hoffman et al. 2018).

[7] The authors calculated energy savings as a percentage of retail sales by dividing the incremental first-year energy efficiency savings by the total volume of retail electric sales in a year for a given utility.

lighting measures represented 7–45% of portfolios' total savings toward first-year goals and that behavioral measures represented 2–27% of total first-year savings.[8] While these program data are a rough proxy for the proportion of short-term measures in a portfolio, they indicate that these measures represent significant proportions of savings in some cases.

A balanced portfolio should include both long- and short-term measures. Short-term measures such as operational and behavioral changes clearly offer some advantages. They are often simpler to implement and can be easier to quickly ramp up.[9] They may also serve as a first step that encourages further investment in deeper and longer-lived energy efficiency savings (Navigant 2013). Short-term measures also offer incremental savings that long-term measures alone cannot achieve, because they address different end uses or because they augment physical measures with behavioral changes that support conservation, like home energy reports, or operational changes that ensure the maintenance of savings, like air-conditioning filter replacement.

Short-term measures can be among the most cost-effective options for meeting the first-year savings goals in place in most states. First-year targets have been successful in driving energy savings. They are relatively simple to understand and explain, and states with such requirements have been successful at communicating their energy savings achievements in common terms.

At the same time, because current policies tend to focus on first-year savings, few states fully consider persistence over time. Where the first-year goals used for implementation are lower than the maximum achievable cost-effective energy efficiency potential, program administrators will have an incentive to focus on measures with low first-year costs and high cost effectiveness, like lighting. Ideally, states would set goals that maximize cost-effective potential. Realistically, first-year savings environments may create perverse incentives to pursue savings that may be cheap on a $/first-year kWh basis but expensive on a $/lifetime kWh basis.[10]

Measures whose lives end before the end of energy efficiency or resource planning horizons may incur reinvestment costs in later years, expenses that may not be included in initial cost-effectiveness calculations. These costs and benefits may come in future cycles rarely contemplated by today's regulators and program administrators. Long-lived measures, on the other hand, may not require the same reinvestment over the time scale considered for resource planning.

One concern is cream skimming, where implementers focus on highly cost-effective measures but miss some savings at a given customer's premises. First-year goals with cost-

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[8] In most cases *Big Savers* found that these were decreases from the proportion of savings attributable to lighting, particularly CFL programs, in earlier cycles.

[9] This correlation does not always hold: some simple measures (LEDs) can have long lives, and some complex and/or expensive measures (e.g., tight ducts) can have short lives.

[10] Such incentives are somewhat mitigated by cost-effectiveness screening that does consider benefits over a measure's lifetime.

effectiveness requirements may encourage cream-skimming by focusing on the most immediately cost-effective savings. In some cases, customer acquisition and set-up costs for a customer site may be high enough that a given measure is unlikely to be cost effective if the customer endeavors to install the same measure later (CPUC 2007). That can leave otherwise cost-effective savings on the table. In contrast, holistic approaches that address a building's envelope or an industrial facility's processes can incorporate opportunities that would otherwise be lost because they would not be cost effective on their own.

Long-lived measures may also be likelier to support a more complete set of nonenergy benefits associated with energy efficiency.[11] In the residential sector, many of the nonenergy benefits associated with energy efficiency—like comfort, home durability, improved safety, increased property value, and emissions reductions—particularly arise in long-term measures like retrofits. Lower vacancy rates and improved property values are associated with longer-term retrofit measures in the multifamily sector, and long-term measures in the commercial sector can deliver risk abatement and improved capital value of equipment and building assets (Russell et al. 2015). Those additional multiple benefits are not regularly quantified in evaluations of energy efficiency programs and are often left out of cost-effectiveness testing. Including such multiple benefits in evaluation and cost-effectiveness testing is another lever that can support use of energy efficiency as a resource over time.

Another consideration is that while first-year savings are easy to understand, track, and benchmark, first-year savings environments do not bear meaningful relationships to the value of savings over time nor to system planning needs. Shorter-lived measures may not last long enough to materially affect longer-term resource needs or to figure in market transformation—i.e., the gradual penetration of efficient measures to the point of lasting change in market behavior whereby efficient measures become the norm (York et al. 2017).

Finally, first-year targets rarely capture all cost-effective energy efficiency, often due to spending caps and unambitious targets. For energy efficiency to be fully valued as a resource, planners need information about the expected performance of efficiency investments over their lifetime and at the end of their expected useful life. Better aligning efficiency policies with the timing of the benefits will lead to investment that procures the most energy efficiency when most needed, especially in cost-constrained environments.

The timing of savings, including the expected duration of those savings, becomes even more critical as states increasingly rely on energy efficiency not only for its role in least-cost system planning but also as a strategy to help with policy objectives such as climate mitigation and other emissions reductions. The need for better lifetime savings estimates will also increase as utility planning processes evolve into more granular time and locational analysis that considers alternatives to traditional infrastructure investments.

[11] This is not always the case; for example, a short-term strategic energy management program may offer many nonenergy benefits; a slightly more efficient heat pump that is a long-term measure may not.

Definitions

Energy efficiency measures or activities are typically described in terms of two spans of time: (1) annual savings associated with the measure that has been installed or the activity that has been initiated, and (2) savings over the life of the measure. While there is generally consistency in definitions for key concepts related to lifetime savings in the industry, some overlapping terms could cause confusion even among the cases selected for this report. We use the following definitions throughout this work.

Measure lifetime or *effective useful life (EUL)* is typically described as the median length of time (years) that an energy efficiency measure is functional and saving energy (Hoffman et al. 2015; Bordner, Siegal, and Skumatz 1994). Measure lifetime is a function of two components: technical life and persistence.

Technical life is the average number of years that a measure operates, based on engineering specifications and standard operating procedures. Technical life may be affected by climate conditions, maintenance methods, and installation practices, among other factors.

Persistence is the change in savings throughout the functional life of a measure. Persistence may decay or degrade over the lifetime of a measure or may increase if the new efficient measure declines in performance at a slower rate than the standard measure it replaces (Hoffman et al. 2015).[12] "Measure persistence" accounts for changes that affect whether the measure is likely to stay in place and operating as planned, like early retirement of equipment, retrofits and remodeling, or home/business turnover. Persistence also includes "savings persistence," accounting for changes that affect savings when a measure is still in place—like changes in operating hours, process/operations, and maintenance—or performance degradation relative to the baseline equipment (Navigant 2018).[13]

Figure 3 shows these relationships.

[12] This was originally called "technical degradation" and is sometimes referred to as "degradation" in the literature.

[13] Programs that encourage early equipment removal or recycling, or programs that add on an efficiency component to another measure with a different life, may call for assessing savings using two or more baselines.

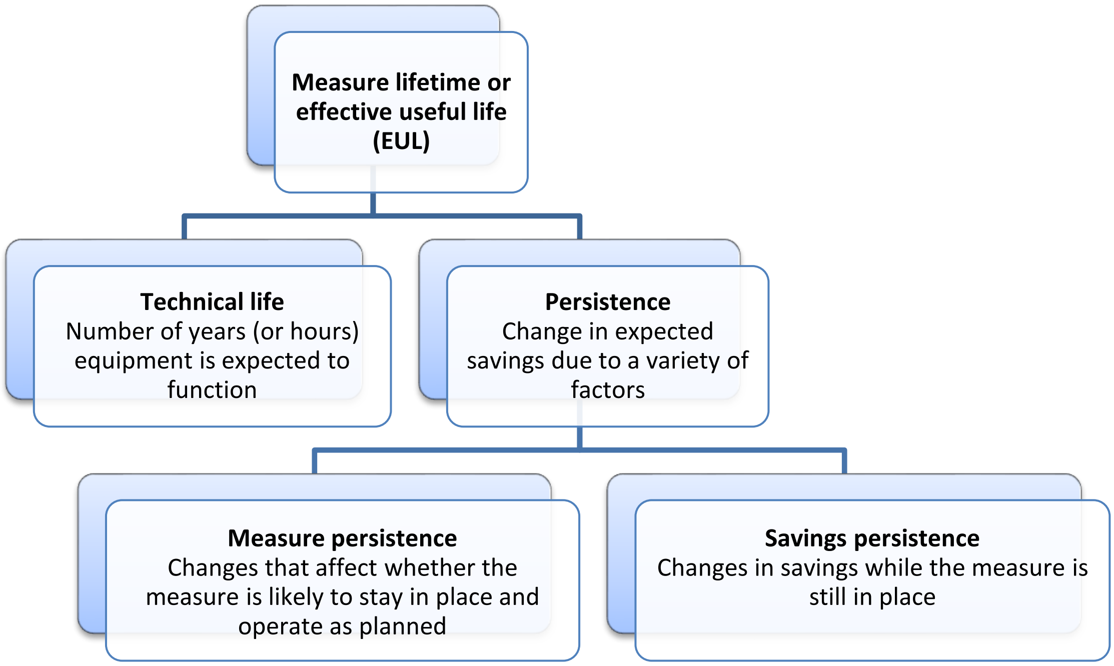

Figure 3. Relationship between aspects of measure lifetime. *Sources:* Navigant 2018; Hoffman et al. 2015.

First-year savings, sometimes called "incremental annual savings," represent annual savings from equipment installed or activities conducted. They are the difference between the energy use of the measure in that year and the energy use of the measure they are replacing (i.e., the baseline).[14] First-year savings do not include savings from measures installed in earlier years that are still in place.

Lifetime savings are a measure of the savings produced over the duration of a measure or activity. Lifetime savings are commonly calculated as the first-year savings times the measure life (in years) but are more accurately characterized as the total energy saved while the measure is in operation, which may vary over time due to changes in either the measure or the baseline against which the measure is compared.

Our review of states' policies finds four types of goals and performance incentives that function as lifetime savings goals.

[14] First-year savings targets ignore persistence (the pattern of energy use over time) and treat savings as constant, with the measure continuing to deliver savings as assumed in the first year. In fact, first-year targets may overstate or understate the value of savings from efficiency measures when the difference between the efficiency measures and the baseline is not constant. Different jurisdictions use different baseline methods, including methods that focus on existing conditions, prevailing codes and standards, or common practice.

Total annual savings evaluate the savings in a particular year from measures installed in that year plus the savings persisting from measures installed in prior years.[15]

Projected savings include the savings from measures installed in a program year as well as the savings from those measures projected throughout their lifetime. Projected savings look forward, so they do not include savings from measures installed in earlier years that are still in place.

Program cycle savings measure the projected savings for a program cycle rather than for specific program years. Goals do not consider savings persisting from measures installed in prior years. Some states, like Wisconsin and Pennsylvania (during its Act 129 Phase II programs) call these lifetime or cumulative savings.

Cumulative savings represent all the savings under a policy or program up through a given year, or the sum of total annual savings through that year. They consider persistence and decay from earlier savings, and they consider the value of savings beyond one specific program year.

Figure 4 depicts these measures of lifetime savings goals as well as first-year savings.

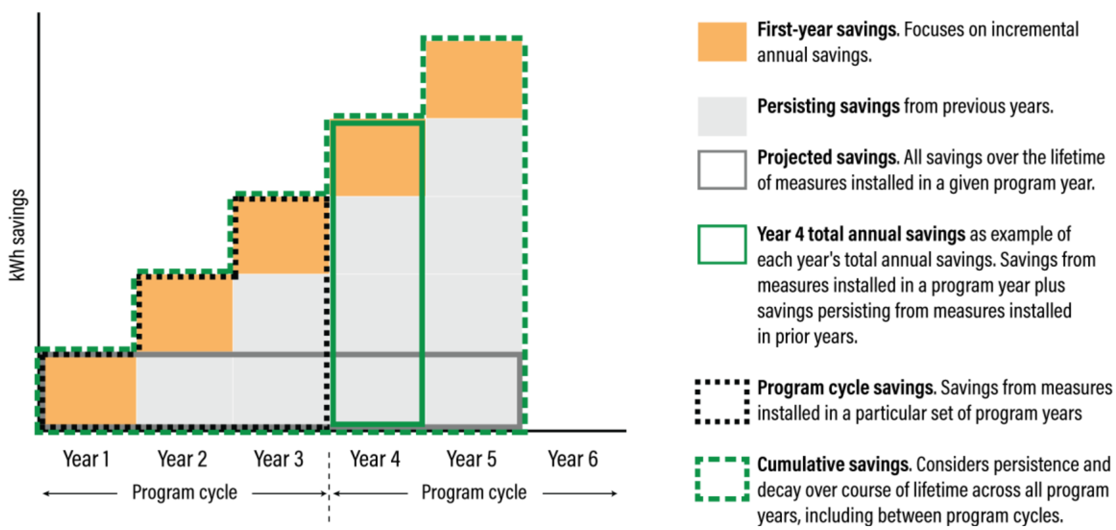

Figure 4. Goal accounting methods for energy efficiency goals

[15] In Illinois, total annual savings are called "cumulative annual persisting savings" (CPAS). In California, total annual savings are called "cumulative" as of a given year. The California Public Utilities Commission (CPUC) defines cumulative as the "annual savings from energy efficiency program efforts up to and including that program year."

Estimating Measure Lifetimes

Program administrators typically document their process for generating savings estimates, including lifetimes, in a technical reference manual (TRM).[16] A measure's EUL is one of as many as 20 or more inputs associated with it in a TRM. As we have seen, EULs combine the technical life of a measure (the number of years the equipment will function) and the persistence, or change in savings over time.

EUL estimates that are used to support policies focusing on lifetime savings are both more complicated to determine and more variable in quality than first-year savings estimates, the primary metric for most goals and shareholder incentives. EULs are not used directly in assessing first-year savings but can be a part of goal setting that uses potential studies that build up estimates of available cost-effective energy efficiency by end use and technology and achievability screens. The magnitude of EULs' effect on lifetime energy savings varies significantly by measure, with more impact on shorter-term measures than on longer ones. For example, the difference between a one- and two-year life measure is quite consequential, but the difference between a 29- and a 30-year life is difficult to measure and of much less consequence.

Figure 5, below, shows lifetime ranges, medians, and averages for several programs from the LBNL DSM Program Database. It demonstrates that there is significant variability in lifetime estimates from measure to measure and in estimates for any given measure. For example, residential appliance recycling programs show savings lifetimes that range from five to nine years for the middle 50% of measure lifetimes. Some measures, like boilers, faucet aerators, and insulation (not shown in figure 5), vary among states, whereas others, like clothes dryers, duct sealing, and heat pumps, have more consistent adopted EUL values across the United States (Skumatz 2012b). Notably, the EULs with significant variation often do not vary with obvious explanatory factors, like climate (Skumatz, Khawaja, and Colby 2009).

[16] TRMs are repositories of information (e.g., memos, spreadsheets, or electronic databases) that document how energy efficiency measure impacts are calculated and the sources of information used in these calculations. They serve as a common reference to provide transparency and consistency to interested stakeholders, and ideally they are updated as market conditions and technology evolve. Detail on TRMs can be found in Schiller et al. (2017).

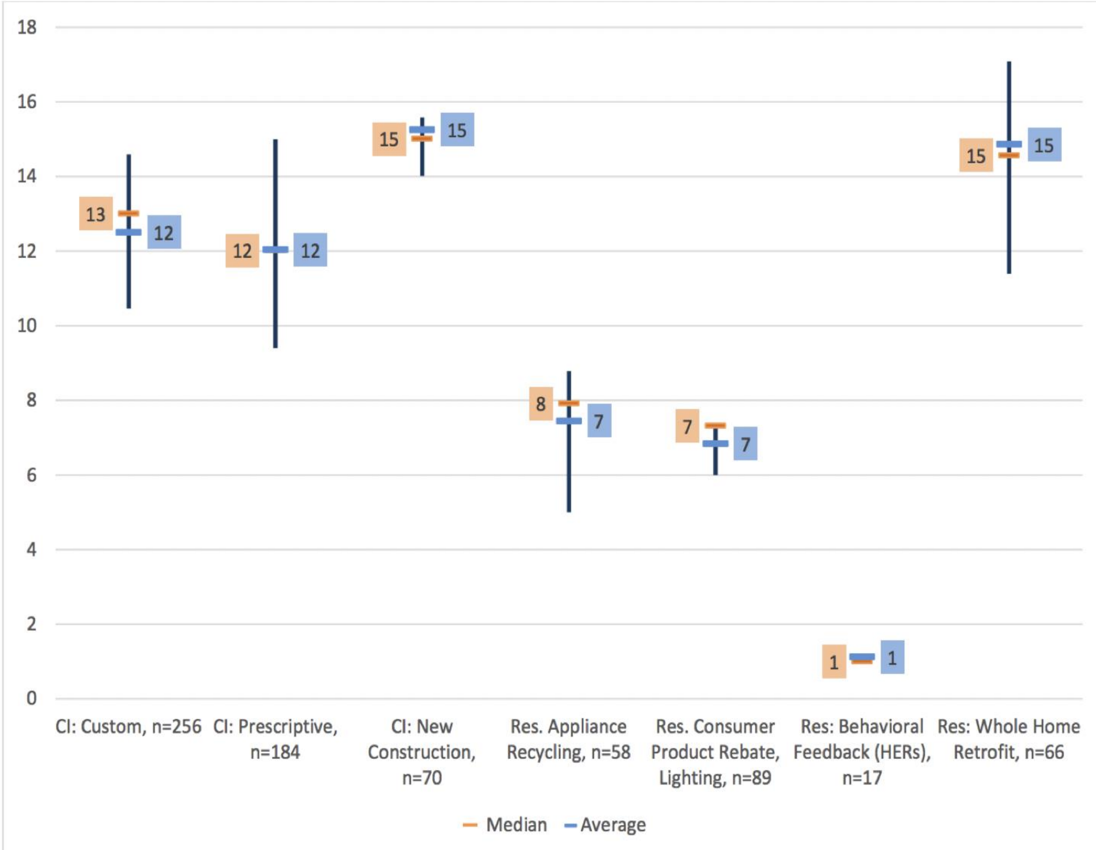

Figure 5. National and sector-level lifetimes for programs, with medians (orange labels and horizontal bars), averages (blue labels and horizontal bars), and interquartile ranges (blue vertical bars). *Source:* Hoffman et al. 2015.

Lawrence Berkeley National Laboratory outlines factors that might generate natural variability. These include policy choices, like caps on measure lifetime (as in Texas and Pennsylvania, for instance), and program design choices, like the type of efficiency project application (e.g., retrofit installation, burnout replacement, or new construction). Variability can also arise from factors particular to the market, including market-specific estimates of operating hours for different facility types; differences in climate, geography, or building stock, like icy conditions that can shorten lifetimes for exterior lighting; or differences in market saturation of efficient equipment, which could shift baselines. Finally, LBNL notes that variability might result from differences in evaluation, measurement, and verification (EM&V) approach and level of effort, including the assumptions used for measure life, the use (or not) of dual baselines, and the choices made about how conservative to be in estimates of measure lifetimes (Hoffman et al. 2015).

Variability is to be expected between TRMs and even for particular measures. However states and program administrators have, over time, consistently underinvested in effective useful life research relative to other key inputs to cost-effectiveness testing, like unit energy savings estimates. Because the policy emphasis has been on first-year savings, existing data may not readily serve policymakers' increasing interest in structuring goals and incentives to support the use of energy efficiency as a resource over its lifetime. Even without changes to goals and incentives, the values currently used often bring uncertainty that should be acknowledged in the calculations used in cost-effectiveness testing, resource planning, and portfolio investment and optimization decisions.[17]

We found wide agreement in the literature and in our interviews that there is a major lack of persistence research in TRMs compared with other key inputs to cost-effectiveness testing. Historically, the perception has been that EULs require more expensive and time-consuming studies to establish values; as a result, studies of effective useful life are quite uncommon.[18] Navigant's recent review of the Illinois TRM did not find any recent studies that holistically reviewed measure lifetimes except for a Northeast Energy Efficiency Partnerships lighting study (Navigant 2018).

Recent meta-analysis of EULs in Illinois (Maoz and Neuman 2018) and California was conducted as part of the creation of a new electronic TRM or "eTRM" (Beitel et al. 2016). This analysis found a preponderance of circular references, many of which lead to studies that are more than 10 years old, focused on grading and verification but not original research, and the use of repeated values for whole categories of (sometime unrelated) equipment. This is consistent with earlier research (Skumatz 2012a). A review of the Consortium for Energy Efficiency (CEE) database and California's Measurement Advisory Council (CALMAC) database found only one EUL study in the CEE database. Values in that database were typically adopted from other states' TRMs, with jurisdiction-specific adjustments either ad hoc or not based on expert conversations. While 95 studies were listed in CALMAC, all were conducted between 1994 and 2006, only half were unique, and most of the studies covered the same common measures (Skumatz 2012b).

There are exceptions in which the process is clearly documented, updated, and based on stakeholder input; these include the Northwest's Regional Technical Forum and Ontario's Technical Reference Manual. And recent policy changes in Illinois and California have renewed efforts in those states to improve EUL values and to better prioritize and target research into measures that are high priority, low quality, or otherwise in question. These efforts may help reduce contention in states with policy frameworks that rely on lifetime savings estimates.

IMPROVING MEASURE LIFETIME ESTIMATES

TRMs should strive to include high-quality measure lifetime estimates where feasible and where these estimates support policy decision making. This requires quality sources, up-to-date or regularly reviewed estimates, and measure lives that are specific enough to address factors that drive significant changes to EULs but which do not misrepresent the level of

[17] It should be acknowledged that there is considerable uncertainty surrounding many elements of resource planning beyond EULs, such as future load forecasts, projections of future fuel prices, other resource cost estimates, and so on, and it would be valuable to conduct sensitivity analysis on key components in the analysis.

[18] Research is also potentially much more time consuming if longitudinal studies over time are needed to track measure persistence.

accuracy associated with their provenance. We outline here the key opportunities to improve measure lifetime estimates.

Source Quality

Lifetime savings estimates come from a wide variety of sources, ranging from complex survival studies to interview panels based on professional judgment. Better information on effective useful life will be required as portfolios shift in composition to include more operational and behavioral programs, like retrocommissioning and strategic energy management, and as efficiency is called on to serve as a resource in more granular locational and time-based contexts.[19]

Generally the best sources are those that (1) utilize high-quality, primary research, (2) are vetted by an independent third party, and (3) are based on a thoughtful accounting of the multiple factors likely to significantly influence measure life, rather than one key factor (e.g., manufacturer warranty). In certain cases additional studies may be merited, depending on the importance of a measure to delivering energy savings in a jurisdiction. Navigant (2018) offers a typology of five levels of source strength that may be useful for assessing the quality of sources to determine which estimates require additional research. We replicate and expand on this typology in Appendix B. While we believe it is useful, we note that the specific methodological characteristics of a study within any of the five categories will materially affect the strength and usefulness of that particular study.

Estimate Updates

Most of the high- or medium-high-strength primary research on measure lifetimes is more than five years old, and much of the literature is more than 15 years old (Skumatz 2012b; Skumatz, Khawaja, and Colby 2009).[20] Exceptions include some research on behavioral measures, like home energy reports, whose persistence has been extensively studied in recent years (Navigant 2017a). For some measures, older studies may still be appropriate, but program administrators may need to update measure lifetimes when there are technology or baseline changes, like emerging technology or new codes and standards. In addition, if administrators ever update equipment, change how it is installed and maintained, or modify where and for whom they deliver programs, they need to think critically about how those changes might affect the duration of savings for the program. Even if the nature of the measure does not change, there may be advances in EM&V methods, new data, or other updates that might affect EULs (Schiller et al. 2017).

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[19] Retrocommissioning is a systematic process for identifying and improving suboptimal energy performance in an existing building's equipment and control systems. Strategic energy management is a set of processes that empower an organization to implement energy management actions and consistently achieve energy performance improvements. See DOE State and Local Solution Center at www.energy.gov/eere/slsc/data-driven-strategic-energy-management.

[20] Many TRMs across the country reference the Database on Energy Efficiency Resources (DEER). Most original references in DEER are from 1999 to 2009, when California still had lifetime goals and the California Public Utilities Commission required studies to verify whether the ex post EUL was different from the planning ex ante EUL value.

Most TRMs are reviewed on a regular schedule every one to three years, or define continual measure-specific review cycles, like the Northwest Regional Technical Forum (RTF), which reviews measures every one to five years depending on the likelihood of changes to key assumptions. Schiller et al. (2017) offers three criteria to prioritize and determine which measures require updates: (1) magnitude of the future impacts associated with the subject measures, (2) potential for improvement of accuracy and consistency of estimates, and (3) costs associated with the updating. Ongoing reviews may not actually result in TRM changes, but the process should assess whether assumptions in the TRM remain valid in light of changes to baseline assumptions or market or program practices. Even regular reviews of assumptions do not guarantee attention to measure life. In both Ontario and Illinois, stakeholders report that measure life estimates received real attention only after goals and shareholder incentives shifted from first-year savings.

Specification of Measure Lives

Given the high cost of lifetime savings studies, it is unsurprising that many TRMs use proxies from related measures for a measure whose effective useful life is unknown. EUL tables that show one value for multiple measures should clearly document the source and type of measure associated with the initial estimate and should not imply that there have been studies assigning lifetimes to all those measures if no such research has been done (Skumatz 2012b). If no higher-quality estimate is available, the TRM should provide justification for why other measures are likely to have a similar measure life.

The reverse is also true: lifetime estimates should be specific enough to be reasonably accurate where there are drastic differences in program variations or market-specific factors to prevent mis-forecasting or misallocation of measures within a portfolio. The Northwest RTF offers the rule of thumb that any factor should be considered substantial and worthy of evaluative review if it changes a measure life by 20% or more. Navigant's research for Illinois recommends that evaluators identify which measures might be influenced by outside factors (e.g., behavior or building type, program delivery method, maintenance practices, and so on), determine which of those factors have the most impact, and then adjust EULs to reflect high-priority factors (Navigant 2018).

Documentation

Clear documentation of sources is important, even where expert judgment is used. EUL tables and technical reference manuals should avoid circular references, as well as documentation that leads to sources whose provenance is unclear. Circular documentation can undermine confidence in effective useful life estimates.

PRIORITIZING MEASURE LIFE RESEARCH

We recommend regular review of lifetime savings estimates along with other cost-effectiveness inputs to ensure that high-quality, relevant, and clearly documented sources are used. Our review of state policy changes finds that policymakers and program administrators refocus research efforts on EULs when policy shifts to value energy efficiency savings beyond the first year. In fact, Illinois and Ontario recently completed measure life reviews to prioritize future research (Navigant 2018; Michaels Energy 2018). Both the California Energy Commission (CEC) and the California Public Utilities Commission (CPUC) have brought on consultants to review effective useful life estimates in light of their respective responsibilities to oversee cumulative energy efficiency targets and program administrator performance. Even in states that continue a first-year framework, these estimates are key inputs to decisions around use of energy efficiency as a resource in planning.

Despite the perception that these studies are expensive, many programs now have multiple years of experience, enabling easier sampling of program cohorts across many years. There are also opportunities to sample for individual measures in a program with multiple measures to reduce study costs. Further, program administrators can find creative ways to focus on the most critical variables. To understand industrial process measure life where it was unlikely that site operators would still remember the initial installation or still employ the same energy managers years later, an Energy Trust of Oregon study focused on whether those industrial operations were still in business performing roughly the same type of functions (MetaResource Group 2011).

Further, there appear to be opportunities for cost sharing among the states that are beginning to prioritize lifetime savings. Before commissioning new research, program administrators and regulators can investigate whether existing research is adaptable to a particular jurisdiction's context, considering differences in the key factors that drive measure lifetime estimates.[21] Where possible, they can leverage other jurisdictions' research, with appropriate documentation to avoid circular or otherwise inappropriate references. In addition, states can design and jointly fund studies with nearby program administrators, perhaps with the support of industry groups, trade associations, national labs, or regional energy efficiency organizations (REEOs). The federal government could also support studies of common program types through efforts like the Department of Energy's Uniform Methods project.

Given the cost associated with measure lifetime estimation, program administrators and state TRM managers cannot conduct high-strength, quality studies on a regular basis for all measures. States should prioritize those measures with the most material impact on the desired outcomes of energy efficiency measures, such as saving energy, reducing demand, and lowering emissions (Navigant 2018). Research should also prioritize measures with the highest level of risk associated with a poor decision based on a bad EUL (e.g., a marginal total resource cost score) and measures with a high level of uncertainty or variability (Skumatz 2012b). Measures with source quality, age, or documentation issues should be flagged for consideration to update or improve estimates where possible. New measures, measures sensitive to persistence, and measures whose underlying technology has changed are also likely important targets for review in many jurisdictions. In addition, research should prioritize measures liable to grow in importance in portfolios rather than those with declining value in meeting desired policy outcomes. These may be new technologies or

[21] Of course, care is required where consistency across jurisdictions is unlikely. For example, utilities' persistence studies of home energy reports are not consistent, due to differences in program tenure and program design; possible variation due to population differences, weather, and other difficult-to-test factors (Ciccone and Smith 2018).

technologies likely to achieve a larger proportion of savings in the future. Finally, states can study measure lifetimes only where there is a viable opportunity or method to do so.

Below, we outline the four types of measures that tend to require particular attention from program administrators and, by extension, from evaluators and regulators: measures with very short or very long lives; those with an operational, behavioral, or control component; and measures requiring a dual baseline.

Very-Short-Life Measures

Short-life measures are those with lives shorter than the length of the typical energy efficiency portfolio cycle (e.g., 2–5 years). Measures with particularly short lives need attention because they are more likely to require reinvestment at the end of their effective useful life. This could be because market transformation has not happened or because the measure is operational or behavioral in nature and requires reinvestment to retain savings. A review of the Michigan Energy Measures Database finds typical examples of short-life measures, including lighting (screw-in CFLs), water heater and boiler tune-ups, energy management controls, and strip curtains (MEMD 2018).

In addition, measures with very short lives can be highly sensitive to measure life in cost-effectiveness testing because changes in this value can have more of an impact on net benefits than is the case with long-life measures. LBNL calculated the range and average total cost of saved energy, including program administrator and participant costs, using measure lifetime values across a sample of programs, and found the greatest variation in measures with short lives (Hoffman et al. 2015).

Very-Long-Life Measures

Long-life measures are those with lives that mirror integrated resource planning horizons of 15 or more years. Long-life measures include new building construction, physical retrofits like windows and insulation, and process changes in industrial applications. While their long life makes them less sensitive in cost-effectiveness testing, their measure life is often highly uncertain because of the difficulty of observing them over their long lifetime.

Some states have regulatory strictures that cap measure lives at a certain number of years. For example, a Pennsylvania statute (Act 129) caps a measure's life at 15 years (General Assembly of Pennsylvania 2008). Others functionally do so with high discount rates that devalue later-year savings.[22] This can frustrate efforts to support the highest-benefit passive, whole-building, or net-zero programs, where the policy framework does not fully value innovation in energy savings.

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[22] Discount rate refers to the interest rate used in cash flow analysis to determine the present value of future benefits from investments. For measures with long measure lives, discount rate becomes critical for valuing those investments. If the discount rate is too high, the benefits in later years will appear to be less than they really are, and if it's too low, it will overvalue longer-lived measures.

Control, Operational, or Behavior-Based Measures

Smart and controllable buildings and systems will become increasingly important in portfolios as energy efficiency is called on as a flexible resource to support renewables integration. Control and operational measures are emerging as important in each sector of the economy. In the large commercial and industrial sector, strategic energy management is a growing source of energy savings. Intelligent efficiency and HVAC, building operator training, and lighting controls are likely to increase in importance in the commercial sector, and smart thermostats and home energy reports are growing in importance in the residential sector.

Because these measures require human intervention or, at a minimum, automation, each presents challenges in measuring and defining its persistence. These measures incentivize behavior that creates both long-term physical changes, like investments, as well as shorter-term changes, like thermostat setbacks. Further, many of these measures are subject to shifting assumptions about climate, occupancy, and operating hours (Skumatz 2009). As a result, additional attention is required to ensure that policymakers and program administrators have the information they need to figure out how best to value these measures in portfolios.

Dual-Baseline Measures

Where programs are designed around an equipment replacement, the years and savings values to be used in a lifetime savings estimate are typically fairly clear. However there are a few key cases where measuring lifetime savings is more complex than measuring the difference between measure and baseline in the first year and multiplying by the measure life. These cases are early replacement, changing standards, and add-on measures that complement but do not replace existing low-efficiency equipment. In these situations, researchers may need to distinguish between different periods of time in the calculation of measure life.

First, early-replacement programs are those in which existing equipment is replaced with energy-efficient equipment before the old equipment stops working or would otherwise be replaced. The "remaining useful life" (RUL) refers to how many more years the existing unit would have lasted and is used to calculate how much additional savings are available from that early replacement and the accelerated turnover of long-life technologies. This, in effect, uses two measure lives for different portions of the savings, one based on the efficiency of the old equipment and one comparing savings to the efficiency of typical new equipment.

Second, some measures require dual baselines because of changing market conditions. This is the case, for instance, with the LEDs that represent a large proportion of many program administrator portfolios. Dual baselines include a baseline corresponding to existing efficiency for the remaining useful life of the existing equipment, and market/standard efficiency for the remainder of the effective useful life of the measure (EPA 2015). Although LEDs typically last about 15 years, the halogens that LEDs displace today last only 1–3 years, suggesting 5–15 baseline product replacements over the life of each LED (see figure 6). Up until 2020, those replacements would be likely to be halogens, but the federal Energy Savings Independence Act of 2007 (EISA) standards begin in 2020, removing most current halogens from the market.

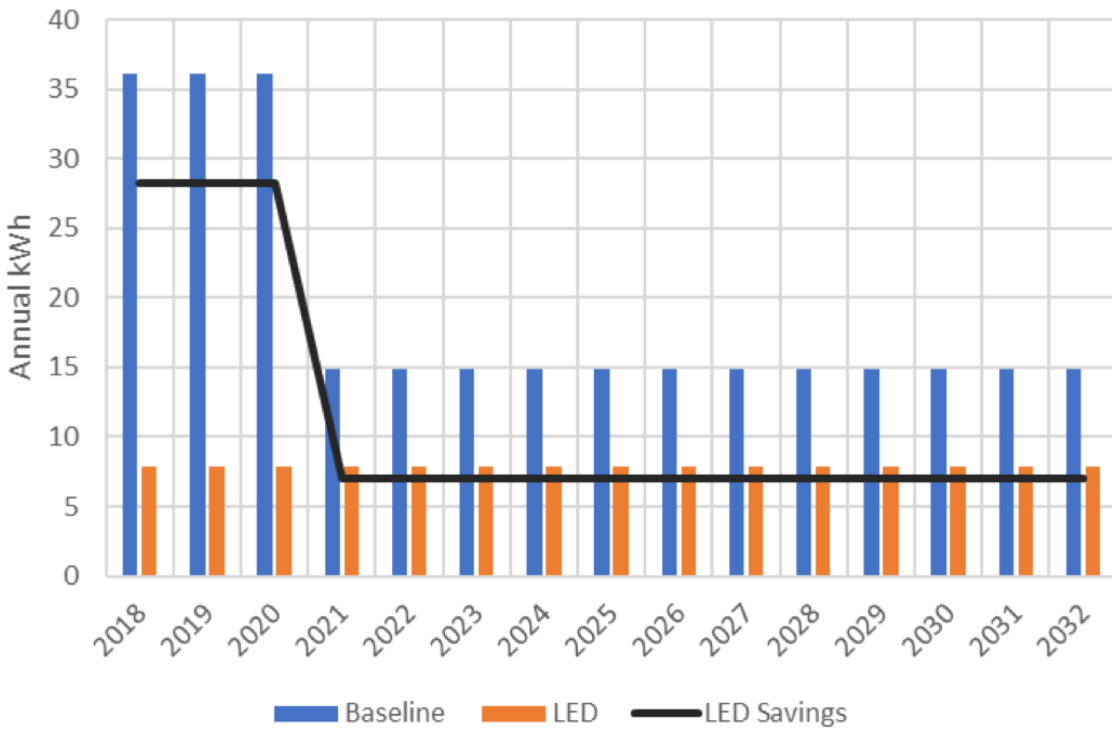

Figure 6. Savings anticipated from 60W-equivalent LED purchased in 2018, where second replacement in 2021 must be EISA efficiency compliant, assuming 840 hrs./year and average halogen life of 2 years, and baseline replacement every odd year, or 7 times during LED life. *Source:* Neme 2018b.

Finally, dual baselines may be necessary for add-on measures that improve the efficiency of an existing system but do not replace it, like prerinse spray valves, demand-controlled ventilation, energy management systems, and variable-speed drives installed on previously constant speed systems. Typically the baseline is the preexisting system without the efficient measure, but some states use dual baselines for add-on measures where the energy use of the existing equipment will predictably decline for reasons not related to the add-on measure, like lighting controls on old T-12 fixtures (ERS and DNV GL 2017).

Applications of Lifetime Savings Estimates

There are four primary applications of lifetime savings estimates in state energy policy:

- Cost effectiveness
- Energy efficiency goals in EERSs
- Performance incentives
- Resource planning

An increasing number of states exhibit a preference for energy efficiency portfolios that deliver savings for a longer time and for policies that offer a clarified view of energy efficiency's value for resource planning and climate policy over time. Several jurisdictions are currently exploring new approaches to system planning to integrate greater levels of distributed resources, including energy efficiency. Some regions, like the Pacific Northwest, have a long history of using energy efficiency as a supply-side resource in resource planning and of considering the potential of energy efficiency over multiple years.

Outside of the United States, measure lifetime estimates are a core component of climate policy. The EU uses these estimates to quantify greenhouse gas emissions reductions, which are based on lifetime abatement strategies. Navigant found that California and the Regional Greenhouse Gas Initiative (RGGI) are the only entities where measure lifetime estimates bear on emissions policy in the United States (Maoz and Neuman 2018).[23]

Beyond the policy context, measure lifetimes are a tool for valuation in financing, when, to justify an investment, a party wants to quantify total benefits of the lifetime of equipment or systems, typically represented as net present value. They are also used in life-cycle assessments of whole buildings to analyze their environmental and social impact.

To explore the policy and evaluation questions associated with measure lifetime in North America, we reviewed the ACEEE State Policy Database and spoke with experts across the country to identify the states leading on treatment of measure lifetime in policy and planning. Ultimately we selected four states and one Canadian province for a more detailed examination. We chose Illinois and Ontario to understand their treatment of measure lifetime in goal setting. Michigan, California, Illinois, and Ontario all have slightly different treatments of measure lifetime in utility shareholder incentives. We picked Oregon in order to include a third-party administrator and a state in the Pacific Northwest, which has robust EM&V and resource planning regimes through the work of the Regional Technical Forum (RTF) and the Northwest Power and Conservation Council (NPCC). This group provides a diverse set of states with different policy environments in terms of restructured versus vertically integrated business models and utility versus third-party administration. Table 1 summarizes these jurisdictions' approaches to EERSs and performance incentives.

Table 1. Approaches to valuing energy efficiency over time in EERSs and incentive mechanisms

State	EERS target type	Incorporation of lifetime savings	Incentive mechanism type
California	First-year	Explicit lifetime incentive	Multifactor
Illinois	Lifetime (electric), first-year (gas)	Explicit lifetime incentive	Rate of return
Michigan	First-year	Implicit and explicit lifetime incentive	Multifactor
Ontario	Lifetime (gas), first-year (electric)	Explicit lifetime incentive	Multifactor
Oregon	First-year	N/A	N/A

[23] California's annual statewide Greenhouse Gas Emission Inventory is an important tool for establishing historical emissions trends and tracking California's progress in reducing GHGs. The inventory provides estimates of anthropogenic GHG emissions within California, as well as emissions associated with imported electricity; natural sources are not included in the inventory. RGGI states include Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. RGGI detail can be found at www.rggi.org.

The sections below, on applications of lifetime savings in policy, reference details from each of these states in order to illustrate the range of options available to states in the policy areas of energy efficiency goals, utility shareholder incentives, and resource planning. Appendix C includes case studies with a detailed description of the policy regime and evaluation practices in each state. It also includes observations generated through interviews with experts working directly on these questions in each state.

COST EFFECTIVENESS

Although cost-effectiveness testing is not the focus of this report, it is a promising area for better valuation of the benefits of energy efficiency savings over time. Program administrators rely on estimates of the lifetime of measures to calculate their cost effectiveness and help determine which efficiency investments to make.[24] Utilities and regulators calculate the value of efficiency by multiplying the net present value of the lifetime energy savings by the avoided costs of building additional capacity and supplying energy. Used as an input to cost-effectiveness screening, these estimates enable planners, program administrators, and policymakers to decide among energy efficiency measures in portfolio planning and between energy efficiency and other supply-side and distributed resources for investment decisions in resource planning (Maoz and Neuman 2018).

Policymakers typically require that energy efficiency programs and other demand-side investments be shown to be cost effective before they are approved, and so some states with "all cost-effective energy efficiency" mandates, like Oregon and California, set targets informed by potential studies. Regulators typically balance the results of potential studies with other concerns, including up-front costs, stakeholder preferences, and political risk, in determining the scope of ambition of energy efficiency goals.

In a potential study, cost effectiveness is generally estimated using the total resource cost test to compare a customer's costs with a utility's avoided cost of supply, although some states use other cost tests. Where the levelized cost of a measure's saved energy is less than a utility's avoided cost of supply, a utility should purchase that marginal unit of energy efficiency instead of the relatively more expensive supply alternative (Neubauer 2014).

However targets based on a typical potential study are unlikely to result in sufficient consideration of the value of energy efficiency over time. First, many such analyses use assumptions that undervalue long-lived measures. Chief among these assumptions are high discount rates, which inherently value savings closer to the present. In addition, avoided cost assumptions can significantly affect 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 analysis (Neubauer 2014). These data and the methodologies used to generate them are infrequently reported, in contrast to measure costs and savings, which are more transparent. Where discount rate assumptions are high and

[24] Program administrators are most often local distribution utilities, although in some states a nonprofit or state-run entity may deliver energy efficiency programs to end-use customers.

avoided cost assumptions are low, longer-lived measures and programs may not make it into a portfolio or target.

Also, cost-effectiveness analysis is typically used as a simple screen to establish a floor for what measures and programs are acceptable. Usually, far more measures and programs will pass than there are budget and other capabilities to implement, so program administrators have a great amount of discretion in choosing the actual portfolio of programs and measures. These choices are overwhelmingly made to facilitate reaching savings goals that have been established (typically annual savings goals) and earning whatever performance incentives have been put in place.

ENERGY EFFICIENCY RESOURCE STANDARD TARGETS

EERSs are a primary driver of energy efficiency savings and investment in states. All of the top 15 energy-saving states in 2017 had an EERS policy in place (Berg 2018).[25] EERS design is consequential for the choices program administrators make for energy efficiency investment. Shifts toward lifetime savings in EERS design are likely to incentivize longer-term measures and consideration of the value of energy efficiency over time.

State Approaches

Of the 27 states with EERSs, 25 currently focus on first-year or incremental annual savings (Illinois and Wisconsin are the exceptions). States set targets in a variety of ways, by policymakers or through a potential study, and may express them as a percentage of savings or a specific megawatt-hour amount. Regulators and program administrators translate these targets into specific annual goals for implementation purposes, often subject to cost restrictions or concerns about achievability. Lifetime savings policies offer a range of alternatives to first-year targets, including limits on short-lived measures, adjustment factors that provide penalties for short-lived measures or bonuses for longer-life measures in efficiency goals and incentives, and changes to the actual structure of the targets themselves.

In practice there are four approaches to setting goals that consider the value of energy efficiency measures over their lifetime:

- *Total annual savings* include the savings in a particular year from measures installed in that year, in addition to the savings persisting from measures installed in prior years. They are called cumulative savings in California and cumulative annual persisting savings (CPAS) in Illinois [26]
- *Projected savings* goals, like those in Ontario, include the savings from measures installed in a program year as well as the savings from those measures projected

[25] 2017 is the most recent year for which complete data are available. See Berg et al. (2018) for more details.

[26] The California Public Utilities Commission defines *cumulative* as the "annual savings from energy efficiency program efforts up to and including that program year." The commission notes that there are three ways to maintain savings at the end of a measure's life: (1) repeating the equivalent measure and incentive again, (2) promoting measures with longer lives that do not need to be replaced as often, and (3) achieving market transformation to ensure that only higher-efficiency options are available (CPUC 2007).

throughout their lifetime. Projected savings look forward so do not include savings from measures installed in earlier years that are still in place.

- *Program cycle savings* measure the projected savings for a program cycle rather than for specific program years. They do not consider savings persisting from measures installed in prior years. Some states, like Wisconsin and Pennsylvania during its Act 129 Phase II programs, call these lifetime or cumulative savings.
- *First-year savings plus portfolio measure minimums* require that a whole portfolio have an average measure life above a specified threshold (e.g., 13 years). Illinois gas utilities have such a structure.

In addition, there are four theoretical approaches to setting EERS goals with an eye to lifetime savings. These are described in the literature but do not appear to be used in practice.

- *Cumulative* savings represent all the savings under a policy or program up through a given year, or the sum of total annual savings through that year. These are not used in goals but are tracked in some states and are important to consider in climate mitigation.
- *Net present value (NPV) of net benefits* values the savings compared with the alternative in the absence of the program by measuring the NPV of the lifetime energy savings times the avoided costs. These goals count achievement on the basis of net benefits rather than savings.
- *First-year savings plus penalty for short-term/bonus for long-lived measures* require that first-year savings from measures with lives below a specified threshold (e.g., 5 years) be multiplied by a factor of less than 1, and savings from measures with lives above a threshold (e.g., 15 years) be multiplied by a factor of more than 1.
- *First-year savings plus short-lived measure limits* require that no more than a certain percentage of savings comes from measures with lives at or below a minimum threshold (e.g., 5 years).

In theory, states whose goals are described as total annual, cumulative, program cycle, or lifetime would address the lifetime value of efficiency because savings from previous program years would be relevant for compliance. However it is important to note that some states, like Arizona, that use "cumulative" or "total annual" to describe their savings requirements do not truly consider lifetime savings.[27] If in practice the "cumulative" savings are only the sum of first-year savings over multiple years, with no allowance for the potential decay of savings from measures installed in earlier years, then the policy is in effect still using a first-year target.

Figure 7 shows EERS states by type of energy savings target.

[27] Arizona's EERS goal is for electricity savings of 22% of retail sales by 2020 and natural gas savings of 6% of retail sales by 2020.

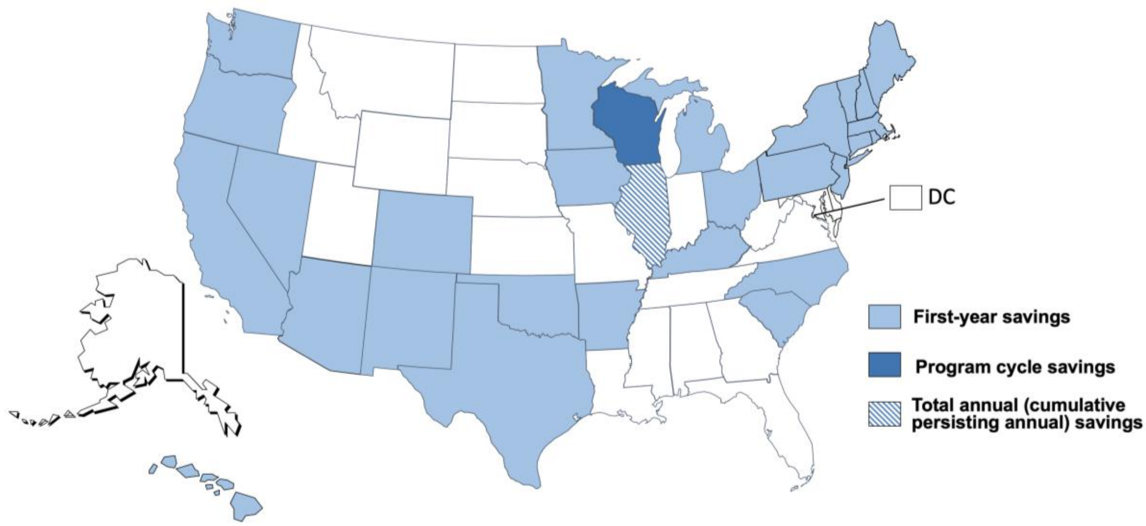

Figure 7. EERS states by type of energy savings target. *Source:* ACEEE State Policy Database with updates.

Only one state, Illinois, structures goals by considering both new incremental measures and the savings persisting from previous years, and factoring in the decay of those persisting savings at the end of their useful life in total annual goals. In addition, Ontario has projected savings goals that consider the lifetime value of energy savings for measures installed in a particular program year. Wisconsin has program cycle goals, set as projected savings for the length of a cycle rather than for a specific program year. However neither Ontario nor Wisconsin explicitly considers savings persisting from previous years.

TOTAL ANNUAL SAVINGS GOALS

Total annual savings are reductions in energy use in a given year from measures installed in that year, in addition to the savings persisting from measures installed in prior years. As mentioned above, in Illinois electric energy efficiency goals are total annual and described as cumulative persisting annual savings (CPAS). The state had first-year goals until the passage of the Future Energy Jobs Act (FEJA) in 2016; energy efficiency advocates pushed for lifetime goals to encourage investment in longer-lived measures. To support a transition from first-year targets to those that value the lifetime of measures, CPAS accounts for annual savings deemed from earlier program cycles and then adds persisting savings tracked for each following year.[28] CPAS distinguishes the difference in value of short-lived measures relative to those with long EULs and savings persistence, takes into account savings from measures installed in previous years, and leads utilities to focus on the long-term value of efficiency resources. It also aligns well with system planning, ensuring that program administrators' plans align more closely with the actual impact of energy efficiency on the system in a given year. However CPAS requires the policy to extend many years into the future, as it does not distinguish between different lives for measures still producing savings in the last year for which goals have been set (Neme 2018a). While ideally EERS

[28] For a given measure, the CPAS is the gross savings for the measure multiplied by the net-to-gross ratio, reduced by the degradation rate and baseline shift for a given calendar year (FEJA 2016).

policies extend far enough into the future to align with resource planning, it can be challenging to create political certainty for investments on those time frames.

From 2004 to 2012, California also had total annual energy savings goals, which were described as cumulative and translated into annual goals similar to CPAS (CPUC 2007). However California went to a first-year goal system in 2012 because of the lack of data and research about savings persistence. These first-year goals are set as “all cost-effective energy efficiency” and incorporate lifetime savings and costs in the potential studies that serve as one input to goal setting. The state is now considering lifetime savings again in response to SB 350, which mandates a doubling of cumulative energy efficiency in buildings by 2030 relative to 2015 (California State Legislature 2015).

Australia has four energy efficiency obligations that measure lifetime savings, in the states of New South Wales, Victoria, and South Australia and in the Australian Capital Territory. Each of these EERS policies measures total savings over the lifetime of an energy savings measure, although some report savings on a total annual basis and others on a cumulative basis (Nadel et al. 2017).

PROJECTED SAVINGS GOALS

Projected savings goals act as the inverse of total annual goals—looking forward to the total value of savings over the lifetime of the measures installed in that program year. Natural gas energy efficiency goals in the province of Ontario are projected savings goals (described there as lifetime or cumulative goals). [29] These goals do not consider persistent savings from previous years. The natural gas utilities’ efficiency activities are overseen by the Ontario Energy Board, which along with stakeholders encouraged a change toward lifetime savings to tip the portfolio toward longer-life measures (OEB 2011a), beginning in the 2012–2014 program cycle and continuing into the 2015–2020 cycle.

Table 2 highlights the cumulative and annual savings over time for Union Gas and Enbridge Gas, the two large gas utilities in Ontario, and includes our rough calculation of measure life based on their annual filings.[30]

[29] Electric energy efficiency targets in the province are first-year goals. These are overseen by another entity, the Independent Electricity System Operator (IESO).

[30] In this case portfolio average measure life is simply calculated by dividing annual net savings into cumulative net savings. This rough calculation does not take into account the time value of energy and assumes constant savings over time, ignoring persistence changes.

Table 2. Union Gas and Enbridge Gas net annual and cumulative savings

	Enbridge Gas			Union Gas		
Program year	Cumulative net savings (m^3)	Annual net savings (m^3)	Rough avg. measure life	Cumulative net savings (m^3)	Annual net savings (m^3)	Rough avg. measure life
2012	1,068,976,932	60,135,753	17.7	2,336,350,638	137,438,488	16.9
2013	826,908,305	47,736,581	17.3	2,820,834,405	179,966,564	15.6
2014	719,842,637	43,540,237	16.5	1,889,459,431	131,825,022	14.3
2015	826,165,451	48,971,556	16.8	1,750,765,480	125,077,193	13.9
2016	837,114,041	50,523,589	16.5	959,435,289	55,970,000	17.1
2017	632,730,000	34,630,000	18.3	1,292,804,261	72,508,214	17.83

Sources: DNV GL 2018; Enbridge Gas 2017, 2018; Union Gas 2017, 2018.

No projected savings (referred to as cumulative savings) or average portfolio measure life data are available for pre-2012 program years. When the projected savings goals were put in place, both Union Gas and Enbridge Gas had rough portfolio average measure lives above 16 years, significantly higher than the average 11.4 years in ACEEE's *2017 Utility Energy Efficiency Scorecard.* Union Gas's portfolio measure life declined steadily, by 18%, in the first four years after the incentive was put in place but rebounded in 2016–2017. In contrast, Enbridge Gas has had relatively constant average measure life, with a decline of only 5% in the first four years after the change from first-year to projected savings, followed by a rebound to all-time high measure lives.

PROGRAM CYCLE SAVINGS GOALS

Program cycle goals measure projected savings but do not attribute savings to specific program years, instead creating goals for a multiyear program cycle (Public Service Commission of Wisconsin 2018). In Wisconsin the regulator approves four-year program cycle savings goals for the third-party administrator, Focus on Energy. The incremental program cycle savings goals are calculated by multiplying annual energy savings potential by the weighted average EUL.[31] The Wisconsin Public Service Commission does not formally set or require interim annual energy savings targets in each individual year, although the program administrator may have informal internal goals for its own planning (J. Fontaine, Focus on Energy performance manager, Public Service Commission of Wisconsin, pers. comm., September 27, 2018). Furthermore, it does not matter which year in the cycle a measure gets installed, because the program administrator tracks performance relative to the four-year goal. As a result, energy efficiency savings may be difficult to translate to a resource planning context, which operates on a more granular time scale. The Wisconsin approach is forward-looking and does not include estimations of savings that persist from measures installed before the relevant cycle. It also does not require estimation of decay rates or savings persistence across calendar years or program cycles.

[31] Potentials for the 2019–2022 cycle are from the 2016 statewide potential study (Garth et al. 2017).

Pennsylvania also had program cycle goals in the Phase II period of its Act 129 programs, from 2013 to 2018. Savings goals were cumulative within the program cycle, such that the savings at the end of the cycle had to "show that the total savings from measures installed during the phase are equal to or greater than the established reduction target." Pennsylvania specified that for any measures installed whose useful life expired before the end of the phase, another measure had to be installed or implemented during the phase to replenish savings from the expired measures.

In Phase III, beginning in 2019, regulators have interpreted the goals as first-year savings instead of program cycle goals. Two arguments from utilities, consumer advocates, and energy efficiency advocates led the Pennsylvania Public Utility Commission to switch. Two of the utilities, PPL and PECO, argued that a goal that includes the sum of incremental annualized energy savings and a requirement to replace expiring savings would overstate potential, because the estimates of incremental annual savings in the potential study already accounted for expiring measures. The Office of Consumer Advocate, meanwhile, highlighted a risk from program cycle savings without annual targets: that a cumulative approach requiring full replacement of expired measures could result in measures being turned on and off during the phase (PA PUC 2015).[32]

OTHER POLICIES

In addition to modifying the goals themselves, states with an interest in encouraging longer-duration measures can set a minimum portfolio average measure life or place a limit on the use of short-term measures in funding or as a percentage of portfolio savings. In Illinois, gas utilities have first-year savings goals but also have a weighted average measure life minimum. This change was implemented in 2018, so its impact on the portfolio is not yet apparent.

Finally, some states issue broader policy guidance to encourage the use of longer-lived measures or market transformation–focused programs, or to encourage the tracking of lifetime savings, as California did in its most recent Energy Efficiency Rolling Portfolio Business Plans (D. 18-05-041). This broader policy guidance can be a first step toward building capacity so program administrators can deliver longer-term savings before firm requirements are set.

Discussion

We find that to date there have been four basic approaches to factoring lifetime savings objectives into energy efficiency goals: total annual savings, projected savings, program cycle savings, and first-year savings with portfolio measure life minimums. Interestingly, we find that some states with nominal cumulative projected savings or total annual goals do not actually represent lifetime approaches. In addition, there are two potential approaches to energy efficiency goals that have been used for shareholder incentives but not for savings

[32] Although the commission accepted the recommendation to switch to credit savings on a first-year basis, the order also continued a requirement that utilities include at least one comprehensive program for residential customers and at least one comprehensive program for nonresidential customers.

goals themselves: NPV of net benefits, and first-year savings with a bonus for long-lived measures. First-year savings with short-lived measure limits does not appear to have been used in policy but theoretically could be an approach to lifetime goals. Table 3 defines and outlines the potential benefits and drawbacks of each of these approaches.[33] The diversity of potential approaches highlights the complexity of reporting and explaining lifetime savings.

The policy impact of these approaches is largely unknown to date. Ontario's programs may have shifted their measure mix toward longer-term measures when the projected savings goals went into effect in 2012, as both utilities reported high average portfolio measure lives (over 16 years) beginning in that program year. Since then, both utilities have largely maintained a long average portfolio measure life, although Union Gas's measure life declined by 18% over the first four years after the incentive went into place before rebounding in recent years. Illinois has not yet reported on its first year of energy efficiency programs under the Future Energy Jobs Act, so its impact is still somewhat uncertain. However filed average measure lives for ComEd and Ameren have grown by 32% and 40%, respectively, from 2017 to 2018 (ComEd 2018; ICC 2018). Further, both Pennsylvania and California have shifted from lifetime to first-year goals in the past due to concern about data quality, misalignment with potential study estimates, or gaming in lifetime policies.

Nonetheless, interviews with utility, regulator, and evaluator stakeholders in Illinois and Ontario reveal increased management and decision-maker attention to energy savings over time. In addition, both states have invested in review of effective useful life estimates by evaluators and have prioritized the measures that require additional research based on those analyses. California, which is considering reinstatement of lifetime savings for investor-owned utilities in response to SB 350, is preemptively reviewing effective useful life estimates at both CEC and CPUC.

Given the small sample size of states with these policies, it is difficult to extrapolate conclusions about the relative merits of these various policy approaches. Rather, we recommend that states consider the benefits and drawbacks of each approach described above if they want to shift the balance of their energy efficiency toward longer-life measures and align energy efficiency portfolios with their policy objectives.

Table 3 summarizes the various approaches to lifetime savings goals.

[33] This articulation of the tradeoffs is based on interviews (in the case of example states), on Energy Futures Group and Optimal Energy's analysis for the Michigan Public Service Commission (Optimal Energy 2013), on Energy Futures Group's presentation to the Illinois Stakeholder Advisory Group (Neme 2018a), and on ACEEE's own analysis.

Table 3. Lifetime energy efficiency goals

Approach	Example	Energy efficiency valuation	Description	Benefits	Drawbacks
Total annual savings	Illinois (electric), some Australian states and territories	Total savings still in effect in a given year, from programs installed in that year and any prior years	Savings persisting from measures installed since a base year are divided by average annual sales over a base period. Savings consider measure life, baseline shifts, and degradation.	Aligns with system planning. Values measures on the basis of their lifetimes.	Requires a lot of research and assumptions about how long savings from each preceding year last. Involves tracking challenges for complex measures. Must set goals many years into future to be effective. Does not distinguish between different lives for measures still producing savings in last year.
Projected savings	Ontario (gas)	Total savings produced over the life of the efficiency measures installed in a given program year	Measure life is multiplied by first-year savings.	Is easier to explain than other lifetime options. Is simple to calculate using data that are already collected for cost-effectiveness screening.	May not address persistence, baseline changes, reinvestment at end of life. May sometimes overvalue future years' benefits relative to cost-effectiveness testing, because it does not discount future values.* Has goals that are more difficult to put in context than goals for first-year savings.
Program cycle savings	Wisconsin (electric and gas), Pennsylvania (2013–2018)	Savings at the end of the program cycle	Savings at the end of the program cycle must show that the total savings from measures installed during the phase are equal to or greater than the established reduction target.	Could enable programs to ramp up to ambitious end-of-cycle goals. Can be combined with requirements to replace measures whose savings expire before the program cycle ends, which focuses attention on persistence.	May not encourage measures whose lives are longer than the program cycle. Is difficult to align with resource planning without annual goals. Creates potential for gaming to turn savings off, then on during the last year of a program cycle.

Approach	Example	Energy efficiency valuation	Description	Benefits	Drawbacks
Cumulative savings	No states, although some track cumulative savings	Total savings produced over the life of the efficiency measures installed across all relevant program years	Approach counts all the savings under a policy or program up through a given year.	Best aligns with climate mitigation, where the total amount of savings over time is critical.	Makes it difficult to determine which years to include in accounting. Requires considerable research and assumptions about how long savings from each preceding year last, and how to value savings in future years. Involves tracking challenges for complex measures.
First-year savings + portfolio measure life minimums	Illinois (gas)	First-year savings from new incremental measures; values efficiency when whole portfolio meets a minimum average measure life	The average portfolio measure life must be more than a specified number of years (e.g., 10).	Maintains simplicity and clarity of first-year goals. Enables flexibility because minimum is at portfolio level, not program or measure level. Creates a clear signal about the value of long-term savings.	Determines measure life minimum arbitrarily. Is a blunt instrument and may not align with the benefits of energy efficiency. May limit low-cost measures that support policy goals beyond system planning.

Approach	Example	Energy efficiency valuation	Description	Benefits	Drawbacks
NPV of net benefits	No examples pertaining to goals. Used for shareholder incentives in many states. Ontario (gas) used total resource cost (TRC) benefits for goals before 2012	Value of savings compared to the alternative in the absence of the program; typically includes a real discount rate applied to future years savings, creating less value for each year's savings the farther out in time you go	The net present value of lifetime energy savings is multiplied by the avoided costs (the costs of building additional capacity and supplying energy, as well as any other categories of avoided costs approved for that jurisdiction).	Aligns savings from short- and long-term measures in proportion to their economic benefits, including value to the system of savings at different times and given the cost of acquiring savings. Includes discounting, but at portfolio level.	Is complex to administer, with high potential for disagreements over measure lives, avoided costs, and other inputs. Requires extensive analysis to set targets based on economic benefits, as there is less information on what it takes to achieve a certain amount of net benefits than there is on how to meet first-year savings. Is difficult to benchmark and set goals—and therefore transaction costs are higher—because avoided costs can differ by time and utility.
First-year savings + portfolio adjustment factors	No examples pertaining to goals, although used for shareholder incentives (Michigan, 2013–2015)	First-year savings from new incremental measures; more value for long-lived measures and less value for short-lived measures; values savings over the life of energy measures installed using adjustment factors (e.g., 3-year measure is worth exactly three times as much as 1-year measure).	First-year savings from measures with lives below a threshold (e.g., 5 years) are multiplied by a penalty factor of less than 1. Savings from measures with lives above a threshold (e.g., 15 years) are multiplied by a bonus factor of more than 1.	Maintains simplicity and clarity of first-year goals. Uses adjustment factors that are simple to implement. Uses s adjustment factor that avoids perverse incentives from blunt instruments.	Determines measure life inflection points between penalties and bonuses arbitrarily. Puts pressure on EUL estimates close to the threshold(s). May limit low-cost measures that support policy goals beyond system planning.

Approach	Example	Energy efficiency valuation	Description	Benefits	Drawbacks
First-year savings + short-lived measure limits	No examples	First-year savings from new incremental measures; caps savings from short-term measures that can be counted toward goal	No more than a certain percentage of savings comes from measures with lives below a threshold (e.g., five years).	Maintains simplicity and clarity of first-year goals and is easily modified. Addresses incentives for short-term measures.	Values all measures below the measure life cap equally without regard to actual value over time. Makes cutoffs arbitrary and likely to produce sharp distinctions that do not reflect meaningful differences in program benefits. May limit low-cost measures that support policy goals beyond system planning.

*** If avoided costs grow at rate similar to the discount rate, they are a closer proxy for economic benefits. Also, concerns about climate change may make efficiency savings *more* valuable in future years because of future carbon costs that may be incorporated into avoided costs.**

UTILITY PERFORMANCE INCENTIVES

Regulated utilities traditionally face disincentives to implementing and scaling up energy efficiency within their territories because efficiency reduces sales and revenues and typically decreases the need for investment in capital infrastructure. Performance incentives partially address this challenge by providing financial returns for energy efficiency achievements, analogous to the financial returns utilities may earn for investments in assets such as generation plants or infrastructure (Nowak et al. 2015).[34] While energy efficiency resource standards or similar targets are the primary driver for utility energy efficiency, changes to utility financial incentives strengthen that motivation (Molina and Kushler 2015). Performance incentive design influences the choices program administrators make about energy efficiency investments. An increased use of lifetime savings as an eligibility requirement or as part of an incentive award structure can encourage better alignment of investments with the value of energy efficiency over time.

A closely related concept is cost recovery for energy efficiency programs. Measure lifetimes are sometimes used in calculations of cost recovery, as described in Appendix A.

State Approaches

Some performance incentive designs provide greater financial rewards for lifetime energy savings, while others primarily incentivize utilities to achieve first-year savings. Performance incentives can encourage lifetime savings through eligibility requirements for the incentive or in the structure of the incentive payout. Many states use a metric related to the lifetime savings from energy efficiency. A number of them use a calculation of the net present value of net benefits to determine incentives, which implicitly includes the lifetime value of efficiency. Some have explicit lifetime-based incentives as well (Relf and Nowak 2018). These variations do not always correlate with EERS target types, nor do they match up directly with the broader categories of performance incentives (Nowak et al. 2015).[35]

For simplicity, we have put performance incentives into three groups based on how they influence utility efficiency program behavior regarding lifetime versus first-year savings: explicit lifetime incentives, implicit lifetime incentives, and first-year incentives. Explicit lifetime incentives are awarded to utilities based on performance against lifetime savings targets, be they cumulative goals, total annual goals, or cumulative goals within a program cycle. Some of these are awarded in conjunction with other metrics in multifactor incentives. First-year incentives are based on first-year performance. Both explicit lifetime incentives and first-year incentives are a mix of energy savings incentives and rate-of-return incentives, the exact mix depending on the state. Implicit lifetime incentives are shared

[34] In addition to performance incentives, revenue decoupling is an important tool to remove the disincentive to engage in energy efficiency.

[35] Nowak (2015) includes four categories of incentives: shared net benefits incentives, where utilities can earn a percentage of the benefits of successful programs; energy savings–based incentives, where utilities can earn a reward for meeting pre-established energy savings goals; multifactor incentives, based on meeting pre-established goals on multiple metrics; and, in some states, rate-of-return incentives, where utilities can earn a rate of return on efficiency spending, sometimes with requirements for energy savings performance.

benefit incentives, where utilities can earn a percentage of the net present value of the benefits over time of their successful energy efficiency programs. Table 4 illustrates these categories for five states and Ontario.

Table 4. Performance incentive examples relative to lifetime savings

State	Incentive savings type	Incentive mechanism type	EERS target type
California	Explicit lifetime incentive	Multifactor	First-year
Illinois	Explicit lifetime incentive	Rate of return	Lifetime
Michigan	Implicit and explicit lifetime incentive	Shared net benefits and multifactor	First-year
Minnesota	Implicit lifetime incentive	Shared net benefits	First-year
Ontario	Explicit lifetime incentive	Multifactor	Lifetime
Rhode Island	First-year incentive	Savings-based	First-year

Illinois's rate-of-return performance incentive is an example of an explicit lifetime incentive for longer-life energy savings measures. As mentioned earlier, the state energy efficiency resource standard is a total annual goal that the state calls cumulative persisting annual savings (CPAS). Eligibility for the incentive is based on whether the year-over-year change in CPAS meets what is called an "applicable annual incremental goal" (Illinois General Assembly 2016). Utility program administrators must achieve enough savings to offset any savings decay before counting progress toward the annual incremental goal. Because the performance incentive ensures that the full value of previous years' goals is addressed before rewarding the new year's achievement, it encourages measures where more units of the measure can be sold or where new customers can be acquired.

Explicit incentives may also be embedded within a multifactor incentive mechanism, which rewards utility performance on multiple metrics. In these cases, the energy savings component explicitly rewards lifetime savings, but the incentive also includes other components such as demand savings, metrics related to low-income customers, or codes and standards performance. For example, California utilities are eligible to earn incentives based on multiple metrics of energy efficiency performance (CPUC 2013). The resource savings part of the incentive calculation multiplies first-year savings by the average portfolio useful measure life, creating a direct incentive for utilities to maximize savings over time.

Implicit lifetime incentives are those that include net economic benefits over time in the calculation of the financial incentive amount. This is common for states using shared net benefits performance incentives. We call these implicit because the eligibility is based on first-year savings, but the financial incentive calculation is based on a percentage of the net present value (NPV) of the positive difference between the costs (efficiency program spending) and the benefits (the dollar valuation of energy savings achieved as a result of the program) over the *expected life of the measure*. Implicit incentives calculated as the NPV of net benefits value all savings over the life of measures and express goals in terms of their actual value. For example, Minnesota's Demand-Side Management benefit incentive mechanism sets eligibility thresholds based on achievement of tiered percentages of first-year sales but awards incentives based on net benefits. This implicit lifetime incentive applies to gas and electric utilities, with the first threshold set at 1% of retail sales for electric utilities and 0.7% of retails sales for gas utilities (Minnesota PUC 2016). Because Minnesota utilities earn incentives based on net benefits, when portfolio managers consider two measures with the same up-front cost, the one that delivers savings over a longer lifetime would yield more net benefits—and therefore a richer incentive.

No states currently have a measure life bonus or adder for long-lived measures, but from 2013–2015 Michigan used a long-life equipment savings multiplier, a 10% savings multiplier awarded to installed measures with a life of 10 years or more. The state later transitioned to lifetime shareholder incentives as one part of a multifactor incentive. Adders can successfully promote longer-lived measures, but these adders are arbitrary and blunt instruments that treat all measure lives above or below a cutoff as equal. Further, poorly designed adders may generate a bonus that accrues mostly to measures that might have been a part of the portfolio anyway (Neme 2018a).

First-year performance incentives reward achievement of first-year savings targets. For example, the electric utility in Rhode Island, Narraganset Electric (National Grid), can earn a performance incentive based on first-year energy savings (70% of the incentive) and demand savings (30% of the incentive). Eligibility for the incentive starts once the utility achieves 75% of the goals. From 75% to 100% of the goal, the incentive ramps up from 1.25% of the spending budget to 5%. From 100% to 125% of each goal, the incentive is 5% of the spending budget times the percentage savings achieved. Because Rhode Island has first-year energy savings goals and annual demand savings goals, and both eligibility and award amounts are based on those goals, this is a first-year performance incentive.

Discussion

Our review finds that most performance incentives incorporate at least some aspect of lifetime savings. This reflects the prevalence of shared net benefit incentives, with their implicit lifetime savings incentive, which are used in 12 out of 29 states offering energy efficiency performance incentives, as of the last ACEEE review of the topic (Relf and Nowak 2018). Explicit incentives are rarer; we found them in California, Illinois, Michigan, and Ontario.

Theoretically, explicit lifetime performance metrics for utility financial incentives could induce significant shifts in portfolio composition toward longer-life measures. We found in our interviews that program administrators are focused on delivery of savings over time in states with lifetime metrics, including Michigan, Ontario, and preliminarily in Illinois. California stakeholders did not find that their explicit lifetime incentives affected program administrator decision making. We did not include states with implicit incentives in the case studies for the report, but early interviews of experts across the country suggested that implicit incentives did not encourage program administrators to focus on longer-term measures or lifetime savings.

Ontario's explicit lifetime incentives have been in place since 2012 for gas programs. The portfolio average measure life for Union Gas and Enbridge is high, exceeding 16 years right after the lifetime goal and incentives policy went into effect. Michigan's explicit lifetime incentive, created in 2017, and its earlier measure life bonus, put in place in 2013, may have had a modest impact on portfolio average measure life. Figure 8 shows that Michigan's portfolio average measure life has slightly increased since the 2009–2012 cycle, when incentives were first-year focused.

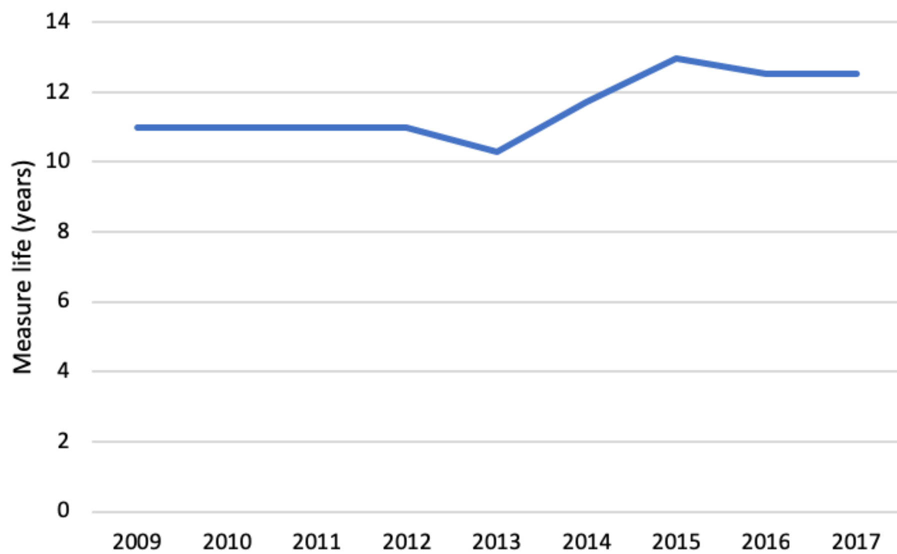

Figure 8. Average of the average portfolio measure life for electricity energy efficiency programs for the two largest utilities in Michigan (DTE and Consumers). *Source:* K. Gould, manager, Energy Waste Reduction Section, Michigan Public Service Commission, pers. comm., August 30, 2018.

Ontario's gas programs and Illinois's electricity programs align EERS goals and shareholder incentives with projected savings and total annual CPAS frameworks, respectively. In comparison, states with explicit lifetime incentives that do not align with EERS goals, like Michigan and California, are noteworthy attempts that represent an incremental improvement, but they are arguably second-best approaches to increasing the focus on lifetime savings. One disadvantage of this misalignment could be a diluted policy signal to program administrators, who might perceive the need to meet two different, sometimes competing, objectives. Nevertheless, to the extent that policymakers want program administrators to balance net economic benefits from first-year and long-term savings, such a mixed approach of goals and shareholder incentives might at least produce some improvements in the overall portfolio.

Performance incentives are an important driver of energy efficiency policy. However performance incentives thus far show a weaker correlation with energy efficiency performance than mandatory targets (Molina and Kushler 2015), so changes to incentive structures may be less impactful than changes to goals. On the other hand, larger financial incentives would place more importance on the design considerations of performance incentives and their impact on program administrators' portfolio design and implementation choices. Where policymakers want to encourage the use of energy efficiency as a long-term resource, or simply to emphasize the acquisition of longer-lived measures, explicit lifetime performance incentives offer another policy tool beyond changes to EERS goals.

RESOURCE PLANNING

EULs and persistence are important inputs to resource planning, both for the process of forecasting new investment needs and for selecting resources to meet those needs. Utilities, regulators, and regional transmission operators conduct planning for generation, transmission, and distribution to ensure the optimal mix of investments that best meets system objectives. Planners look to the expected lifetimes of supply resources, like power plants, transmission lines, and distribution substations, to understand when investment is required and to select the best-fit resources. They also use energy efficiency potential studies as an input to resource plans. These studies' assumptions about measure life influence perceptions about the total potential efficiency resources available in a given jurisdiction.[36]

By carefully considering the lifetime of energy efficiency measures in planning that includes efficiency as a resource, planners can capture the full benefits of efficiency for their customers and system. There are opportunities for energy efficiency to better serve as a long-term system resource in integrated resource planning and as a time- and location-based resource in integrated distribution planning (Baatz, Relf, and Nowak 2018).

A few key indicators help determine whether a state is adequately considering the lifetime of energy efficiency measures in resource planning. First, the state or region should conduct integrated resource planning, transmission planning, and distribution planning processes that include existing energy efficiency as a part of the load forecast and as a part of the potential supply curve to meet system needs (Baatz, Relf, and Nowak 2018). The planning process should fully take into account the value of efficiency savings across measures' lives, with the granularity needed to make resource planning decisions. The planning process should also clearly document assumptions about baseline changes over time, persistence throughout the measures' life, and the treatment of measures at the end of their effective life. Where these factors significantly affect expected energy efficiency savings and their impacts on near-term and mid-term energy and capacity needs, they should be addressed in load forecasting and resource selection.

The four states (California, Illinois, Michigan, and Oregon) and one province (Ontario) included in our study all nominally include energy efficiency in their planning, using the lifetime of those measures rather than first-year savings. However in practice, each of the

[36] Within utility resource planning, approaches to the treatment of measures at the end of their useful life and the assumptions around energy efficiency as a part of a load forecast or a supply curve vary significantly by jurisdiction.

case states has the opportunity to better align its resource planning with the value of energy efficiency across its lifetime.

State and Regional Approaches

Integrated resource planning (IRP) is the process of planning undertaken by a specific utility system or region in order to match supply and demand over a specific period at least cost, or to support some other outcome (e.g., cost risk, environmental concerns). IRP is typically used by vertically integrated utilities that own generation assets, as is the case in Michigan and Oregon, or by state planning agencies, as in the case of Illinois and California. As of 2013, 26 states required utilities to file an IRP, and 10 others had filing requirements for long-term plans like IRPs (Wilson and Biewald 2013).

Each of the jurisdictions we studied estimates the electricity savings from energy efficiency programs and adjusts its load forecast accordingly. Planning is an exercise in assessing the availability of resources over time. Unsurprisingly, the four case jurisdictions all consider electricity energy efficiency over its lifetime in planning, not just the first year of savings. However they differ in which entity conducts the planning, the details of how they account for efficiency, and the extent to which they truly incorporate efficiency as a resource on par with supply-side options.

In California, load forecasting is a part of the Integrated Energy Policy Report managed by the CEC, and demand-side assumptions are based on regular potential studies. Michigan utilities began integrated resource planning in 2016 after passage of PA 342. Oregon investor-owned utilities conduct integrated resource planning separately under the oversight of the Oregon Public Utility Commission, and planning for consumer-owned utilities is through the Northwest Power Plan. In restructured Illinois, each electric utility conducts its own load forecast, which is used for internal planning, for in-state regulatory reporting, and for reporting to PJM and MISO, the regional transmission organizations. In addition, Oregon's and Michigan's investor-owned utilities develop an energy efficiency supply curve based on the cost of specific energy efficiency investments and taking their lifetimes into consideration, which allows system planners to understand the potential demand-side resources available at specific cost thresholds.

Integrated resource planning tends to be passive on the gas side, where energy efficiency investments generate natural gas savings and provide infrastructure investment savings by reducing demand in a broad-based context (Sloan and Dikeos 2018). Neither Ontario nor Illinois actively considers energy efficiency as a resource in gas distribution planning.

Transmission planning may include energy efficiency in the regional peak load forecasts that drive assessment of system needs. In addition, scenarios for meeting demand needs are increasingly evaluating nonwires solutions, including efficiency and other demand-side resources (Baatz, Relf, and Nowak 2018). None of the officials interviewed in case states explicitly brought up lifetime savings in transmission planning. Similarly, the field of integrated distribution resource planning is evolving rapidly. Baatz, Relf, and Nowak (2018) found that 18 of 30 states surveyed included energy efficiency among their distribution resources, with 7 actively including efficiency in resource selection. While electricity energy efficiency has been included among geotargeted (or nonwires alternatives) opportunities in some states, our interviews revealed limited examples where measure life for energy efficiency was a key issue in those contexts.

In general, our review of the five case states found that each considers the lifetime of energy efficiency in its resource planning. States vary more significantly in their treatment of some measure-specific lifetime-related issues in resource planning—in particular, whether to differentiate energy efficiency value over time by measure or to use one value at the portfolio level, their treatment of persistence and baseline changes, and treatment at the end of a measure's useful life.

DIFFERENTIATION BY MEASURE

Some states use one measure lifetime value for the whole portfolio, and others differentiate by measure. For example, DTE in Michigan used an average portfolio measure life of 15 years to model all energy efficiency in its planning to support approval of a new gas-fired combined-cycle power plant (Neme 2018c). In contrast, California utilities and regional planners include measure-specific expectations of effective useful lives in order to build an energy efficiency load forecast, and Oregon uses the same approach to create a supply curve for its utilities.

Where possible, states should build an estimate of savings from the bottom up, accounting for the mix of savings lifetimes from different measures. Of course, not all savings will last as long as the "average savings" of a given energy efficiency portfolio. For example, an analysis of DTE's load forecast found that 12% of the utility's 2018 plan savings were not forecast to persist after the first year, and 24% would not persist past the 10th year (Neme 2018c). An average estimate would obscure an understanding of which efficiency measures will be available to serve as an energy and capacity resource in any given year.

CONSIDERING PERSISTENCE AND DECAY

Where a measure is particularly sensitive to persistence, resource planners should use best available knowledge to base forecasts and supply curves on the savings of that measure including persistence. Most states use effective useful life estimates in their planning, which, as noted above, may not include persistence. Measures that might be particularly sensitive to persistence include smart or programmable thermostats, time-based measures (water heater setbacks, shower timers), and control systems (energy management systems, lighting control systems).

The NW Council uses Regional Technical Forum values as an input to modeling, and the Energy Trust of Oregon typically adopts those assumptions as an input to their forecasting. Its guidelines require that effective useful life estimates consider any factors that affect measure lifetime by at least 20%, including factors that affect persistence, such as operating hours, conditions and practices, and occupancy changes. Illinois's increased consideration of the impact of persistence in goals and performance incentives is translating into resource planning as measure life assumptions are updated in the Technical Reference Manual.

ADDRESSING COMPLEX BASELINES

Measures with complex baselines, in cases of early replacement, changing market conditions, or add-on measures, may deliver significantly different savings throughout their life. Resource planning should account for these complexities where these measures represent a large portion of a portfolio or where a baseline change will have a large impact on savings delivered as a system resource. In California, Illinois, and Oregon, program administrators and regulators noted the impact of the federal EISA lighting standards on baselines and the importance of accounting for projected changes in resource planning (in addition to goal achievement). These states include changes for early replacement and add-on measures as well; for example, California treats variable-frequency drives (VFDs) as an add-on to a motor measure, creating a separate baseline for the motor and deeming only the remaining useful life of the motor for the longer-lifetime VFD equipment (Navigant 2017b).

Michigan does not currently consider baseline changes in lighting in its TRM. Although Ontario considers changing baselines and remaining useful lives (RULs) in its estimates, these do not translate to resource planning for gas.

END-OF-LIFE TREATMENT

Resource planning often extends over long periods to consider long-term investments, usually representing multiple cycles of energy efficiency program planning. As a consequence, states should clearly articulate their assumptions about the contribution of efficiency measures to energy, capacity, and other needs at the end of their effective useful life. Where end-of-measure-life effects can be understood and explained, more study and attention may be required.

The literature does not have one clear empirical answer on the question of end-of-life treatment, and the answer is likely different for different product types, program designs, and market transformation strategies. States vary in their interpretation of how to treat energy efficiency at the end of its useful life. Oregon, and the Northwest region more broadly, make the assumption that measures are replaced at the end of life with equally or more efficient measures. At the other extreme, Illinois's CPAS goals do not count savings beyond the effective useful life of a measure, but it is not yet clear how that translates to resource planning.

California and Michigan take an approach between these two extremes. In California, CEC "Committed"/baseline forecasts, which represent savings from funded utility programs and adopted codes and standards, assume a 50% decay function after the end of the useful life, with no assumption of re-adoption of the same measure or a more efficient one by customers. The additional achievable energy efficiency (AAEE) forecast, which represents future expected energy savings from programs not yet established or funded, assumes no more savings from measures beyond the end of their useful life but assumes a rate of re-adoption by customers that differs by measure, based on the market, but usually hovers around 80%. Michigan has only recently begun the integrated resource planning process, but DTE reports that the potential study that informs its current IRP uses a 50% backslide assumption, where half of the measures require reinvestment.

REGIONAL CAPACITY MARKETS

Less commonly, measure lifetime estimates are used as a part of investment decisions within capacity markets. PJM and ISO New England (ISO-NE) procure generating-capacity resources (measured in megawatts) through auctions three years in advance of when those resources are needed on the system. Inclusion of efficiency in these capacity auctions recognizes the value of efficiency or aggregated efficiency relative to traditional generation resources. Where efficiency is appropriately included in load planning forecasts outside of the resources included in capacity auctions, it can also reduce reserve requirements for capacity procurement, thereby avoiding over-procurement of costly capacity assets (Relf and Baatz 2017). Illinois utility ComEd bids its energy efficiency portfolio into PJM, receiving capacity payments for programs. PJM adjusts the load forecast accordingly to avoid double-counting the savings from ComEd's portfolio. The other states profiled in the report either do not have capacity markets or do not include energy efficiency as a resource in their markets.

These two RTO/ISOs take different approaches to measure lifetimes. ISO-NE provides capacity payments for a measure's full life, while PJM limits capacity payments to four years, even if a measure's life is much longer.[37] Because the added value of long-life measures is not recognized in PJM, it reduces the incentive to invest in such measures. Although there are other drivers of differences between the markets, it is noteworthy that efficiency makes up a larger percentage of total need in ISO-NE than in PJM (Relf and Baatz 2017).

Discussion

Full consideration of energy as a resource requires planning that takes into account key lifetime savings issues. Without full, transparent consideration of the value of efficiency over time, planners might select other options or prioritize poorly among energy efficiency options. Ideally, investment decisions derive from planning processes, and resource planning sends a signal back to the utility's efficiency business units about where to invest efforts and prioritize incentives. This requires clear, transparent valuation of energy efficiency, where planners use the best available information about effective useful life and avoid arbitrary caps on the years of value included in their planning.

Where resource planning properly incorporates energy efficiency, planning processes generally align with lifetime savings. None of the case study states we examined use first-year savings estimates for resource planning. However states with first-year EERS goals, less robust technical reference manual development processes, and newer integrated planning regimes often do not fully account for the nuances of energy savings over the life of measures and programs. In all of the cases states included in our study, policymakers could better document and characterize their understanding of how energy efficiency is valued and treated over time and in resource planning.

In particular, states exhibit a wide variety of approaches to treatment of persistence, dual baselines, and the expected performance at the end of an energy efficiency measure's life. While states may not need to address these lifetime savings issues for all measures, they should at a minimum document lifetime assumptions in resource planning. Additional attention to nuanced issues of persistence, dual baselines, and end-of-measure-life

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[37] An efficiency resource can participate in only four consecutive delivery year auctions, which creates an implicit restriction on the number of years of capacity value an efficiency measure can provide.

performance may be required where measures with these issues represent a large portion of energy efficiency portfolios.

Recommendations

We offer the following recommendations for the stakeholders with the most leverage to shift toward lifetime savings: program administrators, policymakers, and evaluators.

Program administrators manage energy efficiency portfolios and often conduct resource planning. They can better value energy efficiency as a resource over the duration of its life by taking the following actions:

Track lifetime and annual savings, considering the role of persistence, shifting baselines, and end-of-program performance. Regardless of whether a state has lifetime goals or other policies, there is value in tracking both lifetime and annual savings, as the process of tracking savings could encourage program administrators to pay attention to persistence and end-of-measure-life questions. States should clearly document assumptions about how they track savings over time. Regulators can provide a clear template for tracking to ensure consistency across service territories in a given state, and they can request that evaluators measure savings on a cumulative as well as annual basis. Regulators and program administrators can use this tracking to build a narrative for lifetime savings and how it fits in with policy goals.

Deliver long-term savings through new or enhanced program offerings, looking to exemplary program leaders around the country. Lifetime savings regimes create a challenge for utilities whose portfolios have traditionally been weighted toward short-term measures. While some long-term measures may be challenging to implement, program administrators can leverage lessons learned from other states.[38] Regulators can support program administrators by providing guidance to encourage new programs and developing clearly defined criteria for success and funding mechanisms to support program administrators in piloting emerging programs. Program administrators can simultaneously build capacity for participant-focused design considerations, like equity, customer engagement, and nonenergy benefit delivery, maximizing the value of energy efficiency for both the system and customers.

With support from the independent evaluators that analyze the success of efficiency investments and build technical reference manuals, program administrators should:

Review the current state of EUL practice, update measure lifetimes, and prioritize measures and programs for review. Most states prioritize research on data related to first-year savings in their technical reference manuals, but they have an opportunity to review the accuracy and quality of existing data about measure lifetime as well. Key criteria for further research prioritization include impact on desired energy, demand, emissions, or other outcomes; source quality; the level of variability in the measure's EUL; and the level of risk associated with a poor decision. Very short- or long-lived measures, those sensitive to persistence, and

[38] York et al. (2015) includes a review of best practices in emerging areas.

measures with complex baseline questions are important targets for review in many jurisdictions.

Where estimates require updating and a viable research method is available, design studies to assess or update EUL assumptions. If possible, coordinate across utilities within a jurisdiction, and across jurisdictions, to lower the cost of improving measure lifetime estimates. Before commissioning new research, investigate whether existing research is adaptable to a particular jurisdiction's context, considering differences in the key factors that drive measure lifetime estimates. Also if possible, leverage other jurisdictions' research, with appropriate documentation and follow-up to avoid circular or otherwise inappropriate references. Consider regional or national studies where program or measure conditions will be similar.

Policymakers create an environment to support energy efficiency investment. They can take the following actions to ensure the value of energy efficiency over its lifetime:

Modify goals, performance incentives, and policy guidance so that program administrators properly value the persisting savings from installed measures. A variety of mechanisms are available, including lifetime savings, cumulative persisting annual savings, and measure life minimums and bonuses. We find that each of these policy tools successfully focuses program administrator attention on longer-term measures and can lead to the awareness necessary to improve effective useful life estimates. In addition to monolithic changes to policy, states can use multiple goals or multifactor incentives to encourage and balance multiple values within one energy efficiency portfolio. Where possible, policymakers should align goals and incentives. Although either goals or shareholder incentives may be able to independently motivate a focus on long-term savings, ideally policy mechanisms would not provide contradictory signals. However a state that wishes to balance long- and short-term measures might consider a mix of goals and incentives, with some that encourage incremental annual savings and others that encourage persisting savings over time.

Where goals are based on potential studies, ensure that the cost-effectiveness testing and embedded avoided-cost assumptions used in setting these goals adequately value energy efficiency and appropriately quantify all achievable savings potential. States can look to the *National Standard Practice Manual*, which offers a comprehensive framework for assessing the cost effectiveness of energy efficiency resources, including the elements that could make up the range of costs and benefits included in the resource value tests chosen by a given jurisdiction (Woolf et al. 2017). Further, states can expand the evaluation of multiple (nonenergy) benefits and use these benefits as a part of cost-effectiveness testing, which can grow program administrator investment in long-term measures by including benefits associated with deeper energy efficiency savings. States can incorporate these benefits and better value efficiency over time by undertaking comprehensive program evaluations, by assigning an approximate value to benefits, or by adapting values from other states' research to derive estimates for their own programs.

Clarify broad assumptions about end-of-measure-life accounting, decay, and baselines for measures in policy decisions, and detail measure- or program-specific assumptions in technical reference manuals or policy decisions as applicable. Many states do not detail these critical assumptions, leaving even key stakeholders in the dark about the methods used to value energy efficiency as a resource and inhibiting their ability to tell a clear story about the value of energy savings over time. The methods and assumptions adopted to estimate energy efficiency impacts should be fully synchronized with assumptions used for integrated resource planning. This is necessary so the amount and value of the energy efficiency resource can be properly factored into analyses of utility system resource needs.

Conduct, or direct utilities to conduct, transparent planning processes that include energy efficiency as a resource and value efficiency measures for their full lifetime. Fully considering and valuing measure life and persistence are critical both for determining compensation for the resource and for adequately considering EE measure lifetime when forecasting capacity needs. These entities should avoid arbitrary caps on the years of value included in their planning and should use the best available information about effective useful life. As states begin efforts to geotarget resources, utilities should use the best available data about energy efficiency's performance over time to ensure that these resources are also fully valued as a transmission and distribution deferral strategy.

Conclusions

Our review of lifetime energy savings policies, including EERSs, performance incentives, and resource planning, finds a relative lack of attention to the value of energy efficiency over its lifetime. With the exception of assumptions embedded in cost-effectiveness testing and resource planning, most state policies and implementation practices provide little focus on the value of energy efficiency resources over their lifetime. Most EERSs are focused on first-year savings. And while performance incentives often implicitly factor in lifetime savings, few have an explicit focus on savings over the life of efficiency portfolios. These policies, combined with limited energy efficiency program budgets and utility business model challenges, encourage utilities and program administrators to procure those measures that deliver high levels of savings in the first year.

As we detail in this report, some states are turning to new methods to incorporate lifetime savings into energy efficiency policy. One reason for this is concern about incentives that encourage short-term thinking, exacerbating risks like lost potential and misalignment with resource planning and climate policies. In response, policymakers have shifted Ontario gas utilities' and Illinois electric utilities' goals and incentives to projected savings and total annual savings, respectively. California and Minnesota are considering shifts toward lifetime regimes, Minnesota as a part of its potential study planning and California in the implementation of its goal to double energy efficiency in buildings by 2030. Evaluators and utilities in Ontario, Illinois, and California have begun to rigorously assess the effective useful life estimates in their technical reference manuals, prioritizing those measures that require additional research and building a better basis for lifetime policies. States with lifetime policies successfully focus management attention on the value of energy efficiency as a resource. Illinois's filed plans and the last few years of average portfolio measure life in Ontario are promising, especially for Enbridge Gas. The case studies in Appendix C illustrate some of the tradeoffs for these new methods given the increased transaction costs associated with more complex policy mechanisms.

On the other hand, Pennsylvania moved from program cycle savings goals to first-year goals in the most recent phase of its efficiency programs, and California switched from total annual to first-year savings in 2012. California's decision was driven by concerns about limited understanding of measure persistence, whereas Pennsylvania's arose from concerns about misalignment with potential study estimates and the possibility of gaming savings achievement in the last year of a program cycle.

Cost-effectiveness testing offers another promising area for better valuation of the benefits of energy efficiency savings over time. Cost-effectiveness testing influences goal setting and program design in many states. By ensuring that the embedded assumptions (e.g., avoided cost, discount rates) used in setting goals adequately value energy efficiency, these potential studies will be less likely to limit energy efficiency achievement. Further, many of the nonenergy benefits associated with energy efficiency, like comfort, home durability, improved safety, increased housing property value, and emissions reductions, particularly arise in long-term measures like residential retrofits, so long-term measures may be undervalued. Including such multiple benefits in cost-effectiveness testing can support use of energy efficiency as a resource over time.

And while realigning goals and resource planning is critical, our review finds that most states with a performance incentive have at least an implicit lifetime incentive, and several have explicit lifetime incentives. With more robust cost-effectiveness testing requirements, these incentives may provide sufficient support for a balanced portfolio for some states. Although lifetime savings are important, other key policy issues also affect the successful delivery of energy efficiency programs, including the magnitude of targets and performance incentives, the presence of decoupling, the design choices made by program administrators, and the full valuation of multiple benefits in cost-effectiveness testing.

To save customers energy, protect health, and reduce climate emissions, among many other benefits, the policies, planning, cost-effectiveness testing, and data that inform those policies should accurately characterize and encourage capture of that value over time. Without shifts to policies that consider lifetime energy savings, customers, the grid, and society risk missing out on the diverse value from energy efficiency that delivers benefits differently across measures and types of programs. Energy efficiency program administrators, evaluators, resource planners, and long-term climate planners will increasingly need to consider where and when energy efficiency delivers value for their policy objectives. The recent attention on lifetime savings goals and performance incentives in a few leading states offers some encouraging examples, which will provide important information and insight as we observe the implementation of their policy innovations.

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Appendix A. Lifetime Savings in Program Cost Recovery

The core policy drivers of state energy efficiency investment include EERSs and what ACEEE has called the three-legged stool used to address utility financial concerns: program cost recovery, decoupling, and shareholder incentives (Molina and Kushler 2015). Here, we describe the purpose of cost recovery and the approaches to incorporating measure life into cost recovery mechanisms.

The function of program cost recovery is to ensure that utilities are made whole for energy efficiency program direct costs, and all states that offer efficiency programs have such mechanisms in place. In some instances where costs are amortized over time rather than annually recovered and trued up, the measure life included could influence the program investment choices made by program administrators. This is relatively rare. States take a variety of approaches to the amortization period. Maryland uses a five-year measure life for all programs. In Illinois's electric utilities ComEd and Ameren, the amortization period is based on weighted average measure life, and at Duke Energy, in its North Carolina subsidiary, the amortization period varies by the measure life of each program.

The type of cost recovery mechanism has not traditionally been a primary driver of increased energy savings, but additional states are considering amortizing cost recovery over time, either because of a desire to reduce sharp bill impacts from first-year investments, or as a further business model incentive. Amortizing the recovery by the utility of the cost of programs over multiple years may also be considered a rate-of-return incentive if the utility earns a return on the balance after the first year.

Appendix B. Typology of EUL Source Quality

Navigant (2018) offers a typology of five levels of source strength that may be useful for assessing which estimates of effective useful life require additional research. This typology builds on earlier research, including Skumatz (2012b) for the Northwest RTF Operative Guidelines. We replicate and expand on this typology here.

Generally the best sources are those that (1) utilize high-quality, primary research, (2) are vetted by an independent third party, and (3) are based on a thoughtful accounting of the multiple factors likely to significantly influence measure life, rather than on one key factor (e.g., manufacturer warranty). The specific methodological characteristics of a study within any of the five categories will materially affect the strength and usefulness of that particular study.

TYPE 1. HIGHEST STRENGTH

Primary research conducted or vetted by third-party entities such as trade organizations, national labs, or government organizations

Primary research typically involves a large-scale statistical survey (phone or online) or field research to identify whether a measure is still in place and operable, and if not, when it was removed. Primary research may also include laboratory measurement of accelerated failure, which stresses equipment beyond standard field conditions to increase the rate of failure discovery, or stock turnover studies, which use data from survey or shipment sources to estimate lifetime (Skumatz 2012b). Highest-strength research can be costly, cannot be conducted until many years after implementation, and may not be replicable if there are differences in program design or conditions. Statistical analysis to control for exogenous factors and to predict measure lifetimes forward is typically necessary—both because many units may fail long after program cycles are complete, and because some of the measure persistence factors that affect measure life, like business or home turnover, may be particularly difficult to track years later (Skumatz 2011).

The most common examples of highest-strength estimates are documents that the Department of Energy (DOE) produces detailing the analysis behind the federal conservation standards established for each product it regulates. These use a combination of primary, secondary, and industry expert outreach, as well as a stakeholder process to conduct due diligence. Similarly, there are instances of high-quality lighting reports prepared for DOE and the Northeast Energy Efficiency Partnership (Navigant 2018), and for industrial processes and lighting controls for Energy Trust of Oregon (DNV GL 2017).

TYPE 2. MEDIUM-HIGH STRENGTH

Meta-analyses, conducted by third-party organizations, that show some level of evaluating the studies that make up the data set

Many of the analyses most frequently cited by TRMs are conducted by third-party evaluators, representing a review of EUL sources rather than new, original research. These may include an evaluation review of sources combined with third-party review by a working group. For example, the ASHRAE HVAC Service Life Database evaluates different HVAC components in different building environments and use large sample sizes and actual data about equipment failures, but there are gaps in the data and a lack of clarity on the installation conditions and program models included (ASHRAE 2018). However studies that include analysis and evaluation of the sources are relatively rare.

TYPE 3. MEDIUM STRENGTH

Compilations conducted by third-party organizations

Using compilations of adopted values from other agencies can be a good way to generate values where underlying sources and associated quality can be determined, and where the values are reviewed by a third party or stakeholder group. Original sources should be cited, and locatable where applicable. This can be a less costly approach, allowing for more expedient TRM development for states new to energy efficiency. However this approach can also perpetuate errors or rest on outdated information, sources with poor documentation and unknown lineage, or circular references (Schiller et al. 2017). Further, some determinative factors may significantly differ between geographies or program delivery conditions, requiring local adjustments. In addition, these references often do not clarify whether a value represents technical measure life, persistence, or effective useful life. TRMs classified as medium strength provide transparent documentation of sources and avoid circular or undocumented references.

TYPE 4. MEDIUM-LOW STRENGTH

Primary research conducted by interested parties such as manufacturers, distributors, retailers, or installers

Manufacturer warranties and equipment lifetime information can be possible sources for EULs. The life defined may be conservative to help minimize warranty claims against manufacturers (Navigant 2018) or may be biased toward longer life where consumer protections are absent. They are best treated as a benchmark for the right order of magnitude unless the estimation is completed using third-party measurement protocols (Skumatz 2012b). These protocols address potential biases and make key assumptions in the estimate transparent.

TYPE 5. LOW STRENGTH

Source where the basis of measure life is anecdotal

Low-strength estimates include Delphi panels of experts who offer their values or reactions to values. Other examples include stakeholder/expert discussions to negotiate values through meetings. Although these methods often start with values from secondary sources, they are not quantitative and may not do a good job of considering operating conditions or changes specific to particular models (Skumatz 2012b). However these sources may be appropriate or acceptable when clearly documented, when stakeholders agree on the value, and when a regular update schedule is planned to enable better data usage when available.

Appendix C. State Case Studies

This section provides details about the resource planning and policy environments for energy efficiency in California, Illinois, Michigan, Ontario, and Oregon. In each case, we describe why the state was chosen as a case state for this report and describe its energy efficiency goals, shareholder incentives (as applicable), and resource planning with respect to lifetime savings. The case studies are based on our review of regulatory and legislative documents, as well as interviews with key stakeholders in each jurisdiction.

CALIFORNIA

With a robust history of energy efficiency since the 1980s, California is a consistent leader in energy efficiency in ACEEE's *State Scorecard*, placing second in the 2018 edition (Berg et al. 2018). The three investor-owned electric utilities in the state were all in the top 10 of the *2017 Utility Scorecard* (Relf, Baatz, and Nowak 2017). The state's policies for energy efficiency savings have gone back and forth between first-year and total annual savings goals and incentives over time, offering insight into the tradeoffs between approaches.

Energy Efficiency Goals

The California Public Utilities Commission (CPUC) is required to identify all potential achievable cost-effective electricity and natural gas efficiency savings and "establish efficiency targets" for electric and gas corporations to achieve. The targets are currently first-year net savings targets, embedded in the approved 2018–2030 program portfolios and budgets for the state's investor-owned utilities (CPUC 2017).

California's approach to energy efficiency goals has evolved over time. The original goals decision in 2004 established annual (first-year) and cumulative (defined in this report as total annual) goals, with cumulative savings representing the "annual savings from energy efficiency program efforts up to and including that program year" (CPUC 2004). In 2007 the CPUC further clarified the definition of cumulative savings and instructed utilities to report expected cumulative savings in their next portfolio and annual reporting (CPUC 2007). The decision highlighted three ways to "maintain" the equivalent level of savings: repeating an equivalent measure and incentive again as measures expire, promoting measures with longer lives that do not need to be replaced as often, and achieving market transformation to ensure that only higher-efficiency options are available.

Total annual goals remained for the 2009 transition year and 2010–2012 cycle. In the decision approving the 2010–2012 cycle, the CPUC required that utilities make up 50% of the savings decay as measures expire (CPUC 2009). This assumption balanced the commissioners' expectation that some program efforts would result in market transformation, but that some energy-efficient measure uptake might not occur in the absence of program support after the end of a previous measure's life. They recognized that this issue would become more pressing over time as cumulative savings obligations increased and more measures' lives expired. They also noted the importance of additional research into savings persistence over time.

In 2012, the CPUC reversed course and decided not to adopt cumulative goals for the 2013–2014 cycle (CPUC 2012). The order noted that the purpose of cumulative goals was to encourage the utilities to "focus on measures with longer design lives by requiring them to recover savings that would otherwise decay when energy efficiency measures burned out," and that the order provided adequate direction that utilities should continue to focus portfolios on long-term savings. The order described concerns from stakeholders about the treatment of decay over time and stated an intention to study decay and market-transformative effects, especially given the ongoing need for cumulative estimates for long-term procurement planning even with first-year energy efficiency portfolio goals.

SB 350 passed in 2015, requiring that the California Energy Commission (CEC), the state agency tasked with energy policy and planning, establish annual targets (including for investor-owned and publicly owned utilities) that will achieve a doubling of state energy efficiency savings in electric and natural gas end uses by 2030. A September 2017 CPUC order deferred adoption of those cumulative goals pending a CEC assessment of a savings persistence calculation method (CPUC 2017). It is unclear whether future goals will be total annual or truly cumulative in nature.

Figure C1 shows the process for developing energy efficiency savings goals in California.

Figure C1. Process for savings goals development by CPUC and CEC in California. *Source:* LaBonte et al. 2018.

In the interim, utility program administrators will measure and set targets for net life-cycle savings (which appear to be projected savings as defined in this report) over the course of the 2018–2025 cycle. The May 2018 order approving the utilities' business plans includes both first-year annual and life-cycle ex ante (pre-evaluation) gas, electric, and demand savings (CPUC 2018). Life-cycle targets are included across the whole portfolio as well as for disadvantaged communities, hard-to-reach markets, and specific sectors, as shown in table C1. Notably, life-cycle savings are included as a metric, where there is an established target, rather than as an indicator, which is primarily for tracking progress.

Table C1. Life-cycle metrics in California energy efficiency business plans

Sector	Metric
Overall portfolio level	First-year annual and life-cycle ex ante (pre-evaluation) gas, electric, and demand savings (gross and net)
Disadvantaged communities	
Hard-to-reach markets	
Residential single family	
Residential multifamily	First-year annual and life-cycle ex ante (pre-evaluation) gas, electric, and demand savings (gross and net) for multifamily customers (in-unit, common area, and master-metered accounts)
Commercial	First-year annual and life-cycle ex ante (pre-evaluation) gas, electric, and demand savings (gross and net) and as a percentage of overall sectoral usage
Public sector	First-year annualized and life-cycle ex ante (pre-evaluation) gas, electric, and demand savings (gross and net) in sector
Industrial	
Agricultural	

In parallel, the CEC is developing a set of energy efficiency goals in support of the SB 350 targets. In 2017 the CEC published *Revised Senate Bill 350 Doubling Energy Efficiency Savings by 2030*, which established total targets across the state as well as sub-targets for the state's investor-owned (IOU) and publicly owned utilities (Jones et al. 2017). As a part of that report, the CEC defined savings decay and persistence as a key research area. The current status of IOU goals is on hold pending the outcome of that research and any resultant decisions by the CPUC.

Program Administrator Performance Incentives

California has enacted business model reforms to support energy efficiency, including full revenue decoupling and a multifactor incentive called the Energy Savings Performance Incentive (ESPI). ESPI is based on four categories of utility performance as a program administrator: energy efficiency resource savings tied to life-cycle savings estimates (life-cycle savings appear to be projected savings as defined in this report), ex ante review process support, codes and standards advocacy, and non-resource programs. The resource savings component, the largest portion of the incentive, directly incorporates the value of energy savings over time. The award calculation scales annual gross goals to net life-cycle savings values by multiplying annual goals by effective useful life and a set net-to-gross ratio.

Initially the incentive calculation assumed a preset effective useful life of 12 years (for electric) and 15 years (for natural gas) and a net-to-gross ratio of 0.8 (CPUC 2013). Since then the effective useful life has been updated twice (J. Tagnipes, supervisor, Commercial Programs and Portfolio Evaluation Oversight, CPUC, pers. comm., September 25, 2018). Ex post and ex ante savings are built up from individual measures to calculate total life-cycle savings. For example, the order approving 2015 and 2016 ESPI awards used remaining useful life (RUL) values to adjust savings consistent with the Database of Energy Efficiency Resources (DEER) for both early replacement and retrofit add-on measures, demonstrating a granular approach to measure lifetimes in incentive calculations. This commitment to life cycle–based savings for shareholder incentives was reaffirmed in 2017, although the order noted that this requirement is not mandatory but rather should be considered best practice (CPUC 2017).

The ESPI replaced the Risk/Reward Incentive Mechanism (RRIM), which rewarded and penalized utilities for achievement or non-achievement of total annual (called cumulative) savings goals in the 2006–2008, 2009, and 2010–2012 cycles. The RRIM was structured as a shared savings incentive, where net benefits were shared with ratepayers and utility shareholders, with incentive earnings calculated ex post, after program completion. An assessment of the RRIM by the Climate Policy Initiative found that these incentives put pressure on evaluation processes and increase the potential for disputes. While net-to-gross ratios were the primary issue with evaluation under RRIM, total annual incentives could create a similar challenge without robust institutional arrangements for EM&V and dispute resolution where EULs are uncertain (Chandrashekeran, Zuckerman, and Deason 2014).

Resource Planning

California policy treats cost-effective energy efficiency as the highest-priority resource for procurement of new resources. To establish energy efficiency potential, the state conducts regular potential studies as an input to the demand-side assumptions in the Integrated Energy Policy Report (IEPR), used for load forecasting by the CEC and California Independent System Operator (CAISO) and for goal setting for investor-owned utility programs by the CPUC. The Integrated Resource Plan and Long-Term Procurement Plan (IRP-LTPP) is the process for evaluating system, local, and flexibility needs and then authorizing procurement of resources to ensure supply. The publicly owned utilities file integrated resource plans every five years with annual progress reports to the Western Area Power Administration (WAPA). Each publicly owned utility is required to evaluate energy efficiency as an energy supply alternative.

The demand forecast includes a measurement of net cumulative energy efficiency savings. The forecast includes two types of scenarios for savings from investor-owned utilities: committed, or the baseline California Energy Demand Forecast, which are savings from funded utility programs and adopted codes and standards; and AAEE savings, which are incremental to committed and represent future expected energy savings from programs not yet established or funded. The AAEE savings (the mid-case estimate) are the baseline for the cumulative doubling of the energy efficiency goal and are developed by CEC staff in consultation with CPUC and CAISO (CPUC 2016a).

Committed energy efficiency savings use expected useful life data from DEER and assume a 50% decay function after the end of the useful life, with no assumption of re-adoption of the same or more efficient measure by customers. AAEE assumes no more savings from measures beyond the end of their EUL but assumes a rate of re-adoption (~80%) by customers that differs by measure, based on the market (M. Jaske, Senior Policy Analyst, Energy Assessments Division, California Energy Commission, pers. comm., August 28, 2018).

In addition to load forecasting, California allows for incremental energy efficiency investment as a supply resource in distribution resource planning. A 2016 CPUC order identifies principles for procuring additional energy efficiency in geotargeted situations where there is already an all cost-effective energy efficiency mandate (CPUC 2016b). Utilities must ensure that ratepayers are not paying twice for the same service, must ensure the reliability of a service, and must recognize that a distributed energy resource can provide multiple incremental services and be compensated for each service. Resolution E-4889 authorized the Integrated Distributed Energy Resources (IDER) deferred distribution pilot and allowed energy efficiency interventions that propose to provide value by either: (1) accelerating the uptake of measures for which only upstream incentives are currently offered; (2) bringing a greater volume of participation to existing downstream programs through new marketing and/or delivery strategies; or (3) implementing brand-new efficiency strategies.

Sources of Data for Lifetime Savings

Estimates of EUL are maintained in the DEER database, which is transitioning to a new eTRM database through the California Technical Forum (CalTF). As a part of that process, CalTF is reviewing and consolidating savings parameters and calculations, called work papers, across the investor-owned and publicly owned utilities in the state. In reviewing those papers, CalTF staff found that the majority of effective useful life estimates are outdated and that many rely on poor-quality estimates or extrapolations from related technologies.

There are no specific plans in place to update EULs at the CPUC, although the increased transparency and measure consolidation across utilities through the eTRM could support updates to EULs in the future, and the CPUC has issued a broad request for proposals to examine EULs, which could result in changes. The CEC is planning further research on the measure lifetimes of existing programs, including creation of a research agenda to better understand persistence and decay in support of the SB 350 cumulative goals.

ILLINOIS

Illinois is a leader in the Midwest in energy efficiency savings. It placed 12th in the latest ACEEE *State Scorecard* (Berg et al. 2018), and its electricity utilities ComEd and Ameren ranked 8th and 12th, respectively, in the most recent *Utility Scorecard* (Relf, Baatz, and Nowak 2017). Illinois is poised to become a national leader as it begins to implement the Future Energy Jobs Act of 2016, which increased energy efficiency savings goals, consolidated responsibility for energy efficiency in the utilities, and changed both savings goals and performance incentives to focus on the value of energy efficiency savings over time (Illinois General Assembly 2016).

Energy Efficiency Goals

Illinois's electric utilities, with more than 100,000 customers, have had energy efficiency goals in place since 2007, originally established on the basis of incremental annual savings as a percentage of sales (SB 1592). In late 2016, Illinois passed the Future Energy Jobs Act (SB 2814), raising overall electric utility energy efficiency targets to require ComEd and Ameren to achieve cumulative reductions in energy use of 21.5% and 16%, respectively, by 2030.

These new goals count all annual savings from measures installed since 2012 that have not yet reached the end of their useful life, in a total annual goal that the state calls Cumulative Persisting Annual Savings (CPAS). CPAS are defined by FEJA as "the total electric energy savings in each year from measures installed in that year or in previous years, but no earlier than January 1, 2012, that are still operational and providing savings in that year because the measures have not yet reached the end of their useful lives."[39] The goals consider newly acquired incremental savings and lost savings from previously administered measures reaching the end of their measure lifetime. This focus on CPAS includes baseline shifts, like the 15W LED A lamp, which is impacted by the increasing federal EISA standards. It also includes persistence, like the degradation over time associated with behavioral and operational programs when customer touchpoints stop. The presumption in this goal setting is that utilities must reinvest in the same or new incentives and programs in order to maintain savings when a measure reaches the end of its useful life.

Both Ameren and ComEd filed new energy efficiency program plans for 2018–2021 that were approved in September 2017 (Ameren 2017; ComEd 2017). Interviewees report a significant focus from utilities, stakeholders, and regulators on the inclusion of measures with EULs of five years or longer, and on questions of dual baselines, especially for measures affected by the federal EISA lighting standards. Both utilities are required to calculate the weighted average measure life (WAML) of their portfolios each year for the purpose of amortizing costs, so thus far there is one data point of "actual" WAML results. For ComEd, the actual WAML for the 2017 transition period was 8.8 years; the forecast WAML is 10.8 years for 2018 and 11.6 years for 2019 (ComEd 2018), a growth rate of 32% over just two program years. For Ameren, the actual WAML for the 2017 transition period was 8.9 years; the forecast WAML for 2018 and 2019 increases to 12.6 years, for a growth of more than 40% in one program year (ICC 2018).

The Illinois Commerce Commission (ICC) and ComEd both report working on how to best track and present savings data over time; the first example of how utilities choose to narratively describe their savings should be a part of the April 2019 evaluations.

Gas utilities in Illinois also have targets, which started at 0.2% incremental savings beginning in 2011, ramping up to 1.5% savings in 2019 for cumulative savings of 8.6% by 2020 (Illinois General Assembly 2007). These goals can be met either by meeting "annual incremental" savings goals in each year or by demonstrating that the total savings from 2011 to the applicable year were equal to the sum of each annual incremental savings requirement from 2011 to the applicable year. The commission is also allowed to approve modified goals, and it has done so for the past couple of cycles.

Beginning in 2017, in response to stakeholder pressure, the ICC instituted a minimum average portfolio measure life requirement in order to encourage longer-life measures for gas utilities. Nicor Gas's portfolio stipulated an average annual measure life of 12.9 years in the settlement agreement, and the Peoples/North Shore Gas settlement agreement stipulated a 12.3-year average measure life for Peoples and a 9.4-year measure life for North

[39] Future Energy Jobs Act, p. 183. www.ilga.gov/legislation/99/SB/PDF/09900SB2814lv.pdf.

Shore. Each utility negotiated flexibility to shift resources between programs and measures as long as they maintained a portfolio weighted average measure life no less than one year lower than the agreed-upon measure life for Nicor and no less than 0.5 years for Peoples/North Shore Gas. Nicor Gas noted that because of the comparatively limited number of gas end uses, a balanced portfolio of measures would be required anyway to provide all customers with energy efficiency services. As a result, Nicor does not anticipate that this requirement will drastically change its approach to balancing a portfolio of measures.

Program Administrator Performance Incentives

The Future Energy Jobs Act created cost recovery and program incentives for ComEd and Ameren that take into account the value of energy savings over time. It created a cost recovery mechanism to rate base energy efficiency spending, aligning the timing of costs with the timing of savings by amortizing the value of energy efficiency over time. The cost recovery formula rate is set using projected energy efficiency costs for the following year, amortized over the weighted average measure life of the portfolio and reduced for accumulated deferred income taxes.

The bill also created a performance-based mechanism for electricity utilities for investments in energy efficiency, with bonuses for exceeding targets and penalties for falling short. The shareholder incentives are structured relative to the "applicable annual incremental goal" (AAIG), or the difference between the cumulative persisting goal for the target year and the cumulative persisting goal for the previous year. As a result, the utilities must achieve enough savings to offset any lost savings from measures reaching the end of their useful life before counting progress toward the goal (Neme 2017). The incentives are slightly different for Ameren and ComEd, with full rate of return if ComEd reaches 100% of the goal, and full rate of return if Ameren reaches more than 84.4% to 100% of the goal. Both utilities can reach higher tiers of savings and earn additional incentives. They also face penalties below goals, as detailed in table C2.[40]

[40] Note that if the AAIG is reduced, then additional adjustments are made to the performance incentive calculation, as detailed in 220 ILCS 5/8-103B(g)(8)(C) and 220 ILCS 5/8-103B(g)(7)(B)(ii).

Table C2. Return on equity for achievement of energy efficiency goals

Utility	2018–2025		2026–2030	
	Percentage of goal achieved	Return on investment	Percentage of goal achieved	Return on investment
ComEd	≤75%	Minus 200 basis points	≤ 66%	Minus 200 basis points
	More than 75%, less than 100%	Minus 8 basis points per % below goal	More than 66%, less than 100%	Minus 8 basis points per % below goal
	100% or more, less than 125%	Plus 8 basis points per % above goal	100% or more, less than 134%	Plus 8 basis points per % above goal
	≥125%	Plus 200 basis points	≥ 134%	Plus 200 basis points
Ameren	≤ 84.4%	Minus 8 basis points per % below goal	<100%	Minus 6 basis points per % below goal
	More than 84.4%, less than 100%	No change in basis points	100%	No change in basis points
	≥100%	Plus 8 basis points per % above goal	>100%	Plus 6 basis points per % above goal

Note: Basis point reductions and increases are capped at 200 in all cases.

There is no equivalent shareholder incentive for gas utility energy efficiency.

Resource Planning

Illinois is a restructured state, and the main distribution utilities do not own generation assets. The Illinois Power Agency procures resources on behalf of electric utilities. Each utility submits a load forecast, taking into consideration lifetime savings from energy efficiency based on goals. Each electric utility conducts its own load forecast for internal planning, for in-state regulatory reporting, and for reporting to PJM or MISO, the regional transmission organizations. These forecasts are based on available program information, including changes to baselines over time and persistence information where included in the Illinois TRM.

Illinois has not yet explored what happens from a resource planning perspective once market transformation has occurred, when no new net savings are available for a given measure. ComEd suggested that additional research is required to understand the impact of discontinuing an incentive, including the best ways for a utility to exit a market in a manner that preserves efficiency gains already achieved.

Gas resource planning is conducted by the gas distribution companies in Illinois. Gas energy efficiency programs in the state are seven years into operation and have not been incorporated into long-term planning to date.

Sources of Data for Lifetime Savings

Before 2016, measure lifetime estimates impacted cost effectiveness but not goals. With increased scrutiny on lifetime savings, the state decided to review and consider updating these estimates for the version 7.0 update to the Illinois Technical Reference Manual.

To determine which estimates required updating, Navigant completed a review of EUL estimates on behalf of ComEd. It created a framework for evaluating EUL estimates and prioritizing future research based on quality of source and impact on portfolio savings (greater than 2% of savings in a given sector within ComEd's portfolio). Navigant defined three criteria for high-quality sources: age, strength, and documentation. Strength is based on the independence of the source and whether the research is primary, meta-analysis with evaluation of data sets, compilation, or anecdotal.

Navigant reviewed 121 measures' effective useful lives and found 32 measures (26%) that require additional primary research on technical equipment life. These include compressed air components, operational and behavioral measures (advanced lighting control systems, programmable thermostats, smart thermostats, energy management systems, lighting controls, and HVAC controls), and other measures—like economizers, variable-speed drives, retrocommissioning, streetlights, and low-pressure blower systems—where they found lower-quality references. Navigant recommended specific changes to EUL values for 39 measures, about half of them increasing the EUL value and half of them decreasing it (Navigant 2018).

The Illinois TRM states that measure life values are intended to represent "the life of an energy consuming measure, including its equipment life and measure persistence."[41] However most measures have high-quality sources only for technical life, because of the dearth of persistence research available. Navigant found 20 measures that might be highly sensitive to persistence, including control technologies, commercial lighting (given turnover rates of tenants or tenant remodels), and behavior measures.

The version 7.0 TRM update included changes to EULs for 36 measures of the 143 measure updates and included the addition of custom measure lives, which had not previously been included in the prescriptive measure–focused TRM. Research priorities for the next cycle are likely to include high-EUL or persistence-related measures, including baselines for high-performance lighting, persistence for advanced thermostats, lifetime for LED specialty lamps, and adjustments to behavioral savings to account for persistence (VEIC 2018).

MICHIGAN

Like Illinois, Michigan is a leader in the Midwest in energy efficiency savings. It placed 11th in the latest ACEEE *State Scorecard* (Berg et al. 2018), and its electricity utilities DTE and Consumers ranked 13th and 24th, respectively, in the most recent *Utility Scorecard* (Relf, Baatz, and Nowak 2017). Michigan passed PA 342 in late 2016, eliminating a spending cap on energy efficiency programs, enhancing the utility shareholder incentive, and creating a new requirement for utilities to prepare integrated resource plans. Michigan is particularly of interest for its lifetime-oriented shareholder incentives.

Energy Efficiency Goals

Michigan has first-year savings goals, measured as a percentage of incremental electricity savings relative to prior-year sales. In 2008 PA 295 required electric utilities to achieve 0.3%

[41] IL TRM v6.0, Volume 1, Section 3.2 (p. 27). www.ilsag.info/il_trm_version_6.html.

savings in 2009, 0.5% in 2010, 0.75% in 2011, and 1.0% in each year from 2012 to 2015 (Michigan Legislature 2008). The 2016 legislation carried forward 1% electric and 0.75% natural gas efficiency targets.

Program Administrator Performance Incentives

Electric utilities in Michigan do not have a decoupling or lost revenue adjustment mechanism in place, but utilities are eligible to earn shareholder incentives. Michigan's shareholder incentives are structured as a multifactor performance incentive, with most of the award coming from cumulative energy savings, as well as from performance on low-income programs and increases in participation in multi-measure commercial and industrial programs over a baseline year.

Before the recent legislation, PA 295 of 2008 established performance incentives for utilities, with two options. Utilities could request that energy efficiency program costs be capitalized and earn a normal rate of return. Alternatively, they were allowed to request a performance incentive for shareholders if the utilities exceeded the (first-year) annual energy savings target. Performance incentives could not exceed 15% of the total cost of the energy efficiency programs, or 25% of net benefits, whichever was less (Nowak et al. 2015). A commission staff member reports that these incentives typically resulted in an emphasis on short-term measures (K. Gould, manager, Energy Waste Reduction Section, Michigan Public Service Commission, pers. comm., August 30, 2018).

Beginning in 2013, the state experimented with efforts to bolster the installation of longer-lasting measures. At the time, the performance incentive calculation included a 10% savings multiplier awarded to measures installed with a measure life of 10 years or more for DTE and Consumers, the largest utilities (Consumers Energy Company 2014). For Indiana Michigan Power Company and SEMCO Energy Gas Company, the relevant metric was energy savings as a percentage of identified verified cumulative (called lifetime) savings, where lifetime savings were equal to the total of the previous three years' sales in kWh or therms, multiplied by a utility-specific percentage.[42]

The 2016 legislation updating the performance incentive established tiers of eligibility when utilities hit 1.25% and 1.5% annual (first-year) savings. However in implementing the 2016 and the 2008 legislation, the Michigan Public Service Commission established specific parameters for earning the incentive for the utilities that were eligible, including the use of cumulative savings for the majority of the incentive. This switch was negotiated and agreed to in settlement agreements with the utility and certain intervener parties, along with commission staff.

The 2016 legislation and incentive have been clearly successful in driving an increase in energy efficiency commitment; both Consumers and DTE filed energy efficiency plans in response indicating their intention to meet the full 1.5% target. In comparison, the impact of

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[42] Indiana Michigan: Lifetime savings are equal to the average of the previous three years' sales (kWh) times 9.28% in 2014 and 7.19% in 2015. SEMCO Energy Gas: Lifetime savings are equal to the total of the previous three year's sales (therms) times 3.8%

changes in 2013 and 2017 to focus on lifetime savings through a multiplier and then a change to the overall shareholder incentive has been less dramatic. Figure C2 shows the portfolio average measure life over time, which has moderately increased since the 2009–2012 cycle, when incentive were first-year focused.

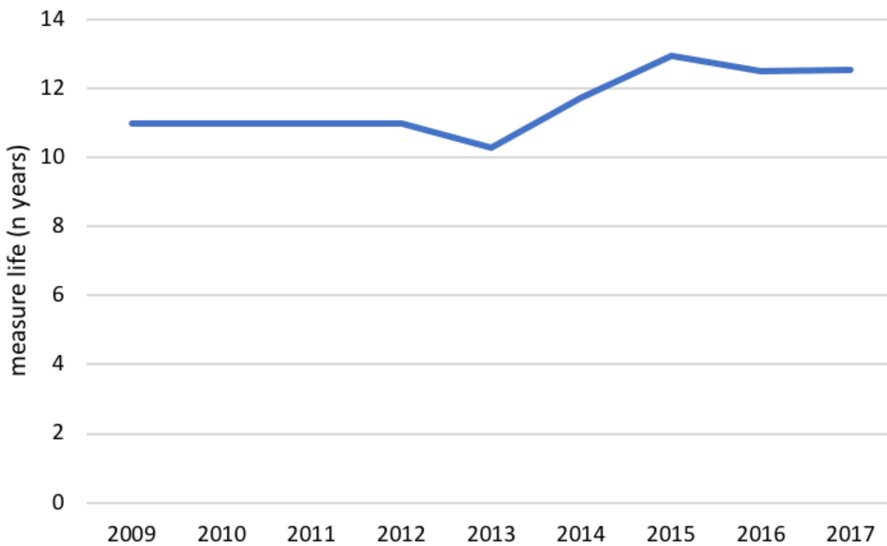

Figure C2. Average of the average portfolio measure life for electricity energy efficiency programs for the two largest utilities in Michigan (DTE and Consumers). *Source:* K. Gould, manager, Energy Waste Reduction Section, Michigan Public Service Commission, pers. comm., August 30, 2018.

DTE staff noted in interviews that as a cold-weather utility, DTE has always included weatherization and HVAC measures as a part of its portfolio, so it did not see the changes to shareholder incentive structure as motivating changes to the portfolio. In contrast, Consumers Energy shifted to monthly and sometimes even weekly tracking of both annual and lifetime savings metrics across its portfolio after the incentives shifted. While the utility has not observed significant shifts in portfolio measure life, Consumers has found that the changes in incentives motivate increased attention to lifetime savings delivery.

Resource Planning

The 2016 legislation created a new requirement for utilities to conduct integrated resource planning. It also requires that key planning parameters, including potential studies for energy efficiency, be reexamined every five years.

Consumers has already submitted its plan, which calls for an increase in energy efficiency to 2.0% per year beginning in 2021 through 2029, and then 2.25% per year in the following decade. These efficiency investments support the plans' overall progress toward an 80% reduction in CO_2 from 2005 levels by 2040. These plans are not highly detailed, so it is difficult to assess the extent to which longer-life measures particularly contribute to the goals. DTE's integrated resource plan is expected to be filed in March 2019, and other utilities have varying filing deadlines from June 2018 until April 2019.

Consumers' IRP assumes that at the end of the useful life of a measure, reinvestment is required to maintain the same level of savings as a resource on the system. DTE reports that the potential study that informs its planning used a 50% backslide assumption, where half of the measures require reinvestment.

Sources of Data for Lifetime Savings

The technical reference manual for Michigan is the Michigan Energy Measures Database (MEMD), which is managed by Morgan Marketing Partners. The MEMD is built out of a set of measure work papers, each of which includes measure lifetime of the baseline as well as improved measures for new construction and replace-on-burnout applications. The MEMD requires reference citations and descriptions of RULs for any early replacement applications (MEMD 2018). Although the MEMD includes baseline shifts and RULs for some measures, it does not appear to be considering dual baselines for the EISA-affected lighting measures (Neme 2018b). Behavioral measures are managed in a separate Michigan Behavioral Resource Manual.

Existing measures are typically reviewed every three years by a technical subcommittee including commission staff. The MEMD process manual includes criteria for prioritization of reviews and calibration research, including the expected contribution to stakeholder portfolio savings estimates (i.e., a large share of current or future planned savings), uncertainty in savings calculations, availability of new data, and length of time since the last modification (MEMD 2018).

ONTARIO

Ontario has a rich history of conducting energy efficiency programs. Demand Side Management programs began as voluntary programs for gas utilities and eventually expanded to electric utilities. The province's gas utilities had one of the first successful performance incentives in North America. Beginning in 2012, the gas programs moved to a lifetime savings regime and so provide the longest example of lifetime savings in North America.

Energy Efficiency Goals

Ontario's Ministry of Energy has a "Conservation First" Framework policy, with electricity energy efficiency savings goals of 30 TWh in 2032, as set forth in the 2013 Long Term Plan and reaffirmed in the 2017 Long Term Plan (Ontario Ministry of Energy 2017). That policy extends to both the electric energy efficiency overseen by the Independent Energy System Operator (IESO) and the gas energy efficiency overseen by the Ontario Energy Board (OEB). OEB has set lifetime natural gas energy efficiency goals as a part of the most recent 2015–2020 Demand Side Management Framework.

Projected savings goals initially emerged in the 2012–2014 gas efficiency portfolio. Before then, utility goals and performance incentives were measured with first-year savings, which resulted in a focus on short-lived residential measures like faucet aerator and showerhead replacement, with minimal focus on insulation or market transformation activities. In 2011, OEB staff recommended "pursuit of deep energy savings" as one of the guiding principles for the DSM portfolio, balanced with maximizing cost-effective savings, equitable access to

DSM programs, and a focus on "lost opportunity" markets (OEB 2011b).[43] Stakeholders intervened as well, concerned about ratepayer prudency and desiring to "ensure their efforts are appropriately focused on those energy savings that will remain in place for the greatest amount of time" (OEB 2014, 11). These efforts resulted in a change toward projected savings targets in the 2012–2014 and 2015–2020 policy frameworks (OEB 2011a, OEB 2014).

In contrast, electric goals in the 2015–2020 Framework are based on first-year rather than projected savings. However the IESO reports savings as "persisting to 2020," the last year of its five-year planning cycle. This reporting mimics program cycle goals (IESO 2018). Electric programs are designed, overseen, and evaluated province-wide by the IESO and delivered by 68 electric utilities across the province. The distinction between first-year and projected goals between electric and gas programs may be attributable to the province's longer history with gas energy efficiency, suggesting that program maturity may be a factor in readiness to move toward lifetime savings. In addition, gas infrastructure in Ontario is managed through an adjudicated process with interveners, whereas electricity energy efficiency is managed directly by the IESO in a nonjudicial structure.

IESO and OEB staff suggest in interviews that this transition to projected savings has been largely successful. Utilities have generally been supportive, as goals were collaboratively designed and are considered feasible by key parties, including the utilities. Table C3 highlights the cumulative and annual savings over time for Union Gas and Enbridge Gas, the two large gas utilities in Ontario, and includes our rough calculation of measure life based on their annual filings.[44] No projected savings or average portfolio measure life data are available for the years before 2012. When the projected savings goals were put in place, both Union Gas and Enbridge Gas had rough portfolio average measure lives above 16 years, significantly higher than the average 11.4 years in the *2017 Utility Scorecard.* Union Gas's portfolio measure life declined steadily by 18% after the policy change, but rebounded in recent years. Enbridge Gas has had relatively constant average measure life, with a decline of only 5% after the change from first-year to projected savings, also followed by a rebound in average portfolio measure life.

[43] The OEB defined deep energy savings as "measures that result in long-term savings, such as thermal envelope improvements (e.g., wall and attic insulation)." It defined lost opportunity markets as "DSM opportunities that, if not undertaken during the current planning period, will no longer be available or will be substantially more expensive to implement in a subsequent planning period" (OEB 2011b, 10).

[44] In this case portfolio average measure life is simply calculated by dividing annual net savings into cumulative net savings. This rough calculation does not take into account the time value of energy over time and assumes constant savings over time, ignoring persistence changes.

Table C3. Union Gas and Enbridge Gas net annual and cumulative savings

	Enbridge Gas			Union Gas		
Program year	Cumulative net savings (m^3)	Annual net savings (m^3)	Rough avg. measure life	Cumulative net savings (m^3)	Annual net savings (m^3)	Rough av. measure life
2012	1,068,976,932	60,135,753	17.7	2,336,350,638	137,438,488	16.9
2013	826,908,305	47,736,581	17.3	2,820,834,405	179,966,564	15.6
2014	719,842,637	43,540,237	16.5	1,889,459,431	131,825,022	14.3
2015	826,165,451	48,971,556	16.8	1,750,765,480	125,077,193	13.9
2016	837,114,041	50,523,589	16.5	959,435,289	55,970,000	17.1
2017	632,730,000	34,630,000	18.3	1,292,804,261	72,508,214	17.83

Sources: DNV GL 2018; Enbridge Gas 2017, 2018; Union Gas 2017, 2018.

Program Administrator Performance Incentives

The OEB prioritizes alignment of DSM with supply-side resources. Since 1993, its policy has been that "approved DSM costs should be treated consistently with prudent supply-side costs. Long-term DSM investments should be included in rate base and short-term expenditures expensed as part of the utility's cost of service."[45] Today program administrator performance incentives for gas utilities are based on a "DSM scorecard" or multifactor approach, with the largest portion associated with resource acquisition of lifetime savings. The DSM Framework sets a maximum incentive, or annual cap, for each of the utilities of $10.45 million, escalated for inflation (OEB 2016). This cap is allocated among generic program types (i.e., resource acquisition, low-income, large-volume, and market transformation programs) based on their approved DSM budget shares (OEB 20111a). Resource acquisition is structured as a projected savings incentive for all sectors.

Eligibility for the incentive is based on tiered performance, with no incentive below 75% and a linearly scaled incentive between 75 and 150%, with a pivot point at 100% to encourage performance beyond the goal (OEB 2016). Forty percent of the maximum incentive available is provided for performance achieving a scorecard-weighted score of 100% level, with the remaining 60% available for performance at the 150% level (OEB 2011a).

Figure C3 shows the percentage of scorecard goals achieved in each category from 2012 to 2015 for one of the major utilities, Union Gas.

[45] E.B.O. 169-III Report of the Board, dated July 23, 1993.

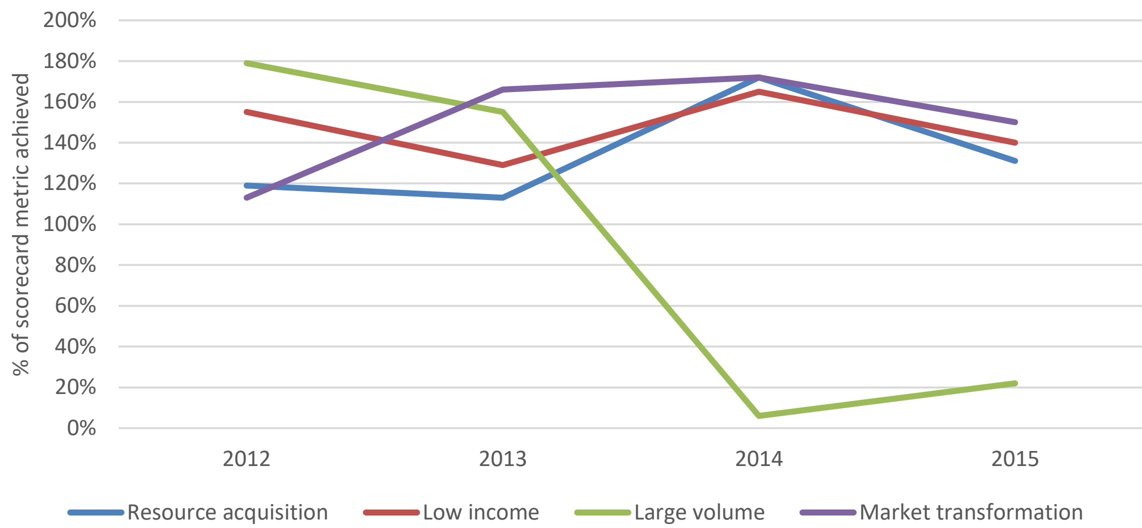

Figure C3. Union Gas DSM incentive results, 2012–2015. *Source:* Union Gas 2013, 2014, 2015, 2017.

The figure shows strong achievement—often beyond the 150% of scorecard maximum—in the resource acquisition, market transformation, and low-income lifetime savings categories. In some cases, achievement was beyond the maximum incentive at 150%. Large-volume (large commercial and industrial custom projects) savings have seen mixed results in recent years.

These incentives evolved from earlier ones that rewarded the utilities with a portion of the present value of overall economic benefits produced by DSM programs during the 2006 Generic DSM proceeding term (2007–2011). The OEB shifted to the scorecard approach for the 2012–2014 period, specifically noting that one behavior to reward would be "an increase in the delivery of long-life energy efficiency measures" (OEB 2014, 20). A much earlier review of the net economic benefits–based incentive mechanism found that the incentives led to emphasis on short-term savings from retrofits as well as limited investment in market transformation and more difficult markets like new construction and equipment replacement (Neme 2004).[46]

Program administrator performance incentives for electric utilities are smaller in scale than the incentives offered to gas utilities. The incentives are tied to first-year savings. However in order for an electrical distribution company to earn its performance incentives, all savings have to persist until the end of the framework (or cycle), suggesting that eligibility for incentives is structured to support life-cycle savings.

Resource Planning

Ontario's resource planning framework dates to the 2013 Long-Term Plan. The Ministry of Energy committed to work with its agencies to ensure they put conservation first in their

[46] In 2002, 44% of Enbridge's annual incremental residential gas savings and 57% of residential net benefits came from low-flow showerhead, hot water pipe wrap, and hot water tank setback measures. (Neme 2004)

planning, approval, and procurement processes (Ontario Ministry of Energy 2013). The ministry also committed to work with the OEB to incorporate the policy of conservation first into distributor planning processes for both electricity and natural gas utilities.

In the 2014 DSM Framework document, the OEB required that all future capital projects provide evidence of how DSM has been considered as an alternative for reducing or deferring the project. The framework notes that the utility may apply for incremental funds to administer a specific DSM program where a system constraint has been identified with an opportunity for reduction or deferral. The board also asked the gas utilities to outline how they planned to include DSM as a part of future infrastructure planning efforts (OEB 2014). In response, the utilities commissioned ICF to study best practices in gas infrastructure alternatives from DSM. This research found that "non-pipeline" alternatives are only rarely considered for gas in other jurisdictions, and that while some infrastructure investments may be reduced through the use of targeted DSM, changes in policy and utility planning processes would be required (Sloan and Dikeos 2018). ICF suggested additional research to confirm that DSM can fill this role. Enbridge committed to monitor the impacts of DSM programs and higher-efficiency equipment on peak period demand. While this is an issue of interest, energy efficiency is not currently treated as a supply-side resource for natural gas planning in Ontario.

Sources of Data for Lifetime Savings

The data for gas measure lifetimes is managed in a TRM. When the policy regime shifted to lifetime savings in the 2012–2014 period, the technical evaluation committee reviewed the rigor with which input assumptions, including effective useful lives, were developed. Intervenors were vocal about the need to improve the quality of input data, especially the need to eliminate circular references. The TRM is updated on a yearly basis.

Since then, extensive work has been done to validate EULs, especially on custom measures. In 2018 the OEB commissioned research to review the top 20 commercial and industrial measure lives used by the utilities, to determine if they are reasonable and appropriate in light of the current literature and to determine whether additional, Ontario-specific measure life research is warranted (Michaels Energy 2018). That research found that 15 of the 20 measures use lifetime estimates consistent with the available literature, and that the rest warranted changes to reduce their measure life by five to six years each.[47] The research also recommended additional primary research on pipe insulation measures and building automation systems.

The IESO is reviewing its evaluation process for electricity energy efficiency and may make changes to how it develops and updates TRM estimates.

[47] The study recommended reducing the measure life of boiler controls, VFD for make-up air units, infiltration controls, pipe insulation, and building automation systems.

OREGON

Oregon has a well-established history of delivering energy efficiency programs through its third-party administrator, Energy Trust of Oregon (ETO). The state ranked seventh in the most recent ACEEE *State Scorecard*, and the utility PGE ranked ninth in the *Utility Scorecard* with program data from ETO (Berg et al. 2018; Relf, Baatz, and Nowak 2017). We included Oregon to highlight the experience with lifetime savings at a statewide third-party administrator, which is the dominant energy efficiency delivery model in six states. In addition, Oregon is a part of the Northwest region, so its utilities are a part of the rich history of integrated resource planning by the NW Power and Conservation Council and the more recent developments in collaborative evaluation, measurement, and verification at the Regional Technical Forum.

Energy Efficiency Goals

ETO sets specific goals, collaboratively developed with regulated utilities and the Oregon Public Utilities Commission (OR PUC) in its annual budget and action plan (SB 1149, SB 838). The most recent action plan (2018–2019) includes goals of net and gross average megawatts (aMW) for electricity savings and net and gross annual therms for natural gas savings (Energy Trust of Oregon 2017).[48] These are first-year goals.

The annual action plan does not include lifetime savings goals but does include levelized cost thresholds, as well as a cost-effectiveness framework that examines the net present value of savings over time based on avoided costs. Each of these incorporates the value of energy savings over time, discounted to the present.

Program Administrator Performance Incentives

As a nonprofit government agency, ETO receives no performance incentives. However OR PUC establishes metrics, called quantifiable performance measures, to define its expectations of ETO's performance (Oregon PUC 2017). These are different from targets or goals and are intended to provide early indicators of poor program performance, which might signal that PUC intervention is required. The 2017 measures focus on savings in aMW and levelized costs in $/kWh across ETO and by utility.

Resource Planning

Oregon resource planning occurs at the regional level through the Northwest Power and Conservation Council and at the local distribution utility level through utility integrated resource planning. The regional plan has no legal or regulatory standing for Oregon's investor-owned utilities but is considered a valuable reference point for utility planning. The regional plan does have important influence with respect to the Bonneville Power Administration, which provides a large share of the power resources for the Northwest's consumer-owned utilities, including those in Oregon. The Energy Trust of Oregon projects

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[48] aMW measures generating capability, which is less than generating capacity in MW (total possible output). It is equivalent to the maximum amount of power a generating plant is *capable* of producing over the course of an average year (Northwest Power and Conservation Council 2018).

the energy efficiency potential to be acquired as a part of the integrated resource plan of each utility in the state in its Resource Assessment Model.

In each context, energy efficiency is used both in load forecasting and as a supply-side resource to address any resource gaps. The efficiency supply curves in NPCC's Regional Plan and Energy Trust of Oregon's modeling show how much efficiency savings are available at different cost levels, based on an aggregation of the savings and levelized costs of individual classes of measures. As costs are increased, more measures become available. There are two categories of efficiency supply curves. The first is lost-opportunity efficiency, whose availability over time is determined by economic activity and appliance replacement patterns constrained by limits on availability, allowed development rates, and maximum penetration rate assumptions. The second is discretionary or non-lost-opportunity efficiency, an aggregation of measures that can be implemented at any time but are nonetheless constrained by maximum penetration rate assumptions (Northwest Power and Conservation Council 2011).

The statute that established the Northwest Power and Conservation Council says the council is to consider the cost of resources over their "effective life." The pattern of savings over time assumed for energy efficiency measures includes "how the potential develops over future years, the seasonal and hourly shape of the savings, and the amount of reduction expected to peak demand"; these estimates are developed in the Regional Technical Forum workbooks and then applied in the plan's efficiency assessment. The lifetimes at Oregon's investor-owned utilities are based on the ETO Resource Assessment Model, which typically uses RTF data, except where the local context or program delivery model differs from the RTF assumptions.

In both contexts, planners assume that a given measure will be replaced at the end of its useful life by a measure with at least the same efficiency. The second plan, adopted in 1986, based the levelized costs used to generate supply curves for conservation measures on the capital, operational, and maintenance expenditures over the lifetime of the conservation measure. The system modeled aggregate classes of measures rather than individual measures, so they included capital replacement costs for any measures with lifetimes shorter than the lifetime of the primary measure in the portfolio (e.g., caulking and weather-stripping, which have shorter lifetimes than insulation). This guidance was reiterated in the third plan, as well as in recent guidance (Northwest Power and Conservation Council 2011).

Sources of Data for Lifetime Savings

Energy efficiency measure estimates in the Northwest are developed by the RTF, a multi-stakeholder group with staff based at the Northwest Power and Conservation Council. All measures are updated regularly (every 1–5 years), and each update includes a review of the measure life for each measure.

The RTF provides a set of Operational Guidelines, including a chapter on measure life, which is used for determining lifetime savings and cost effectiveness in its protocols (RTF 2018). The protocols specify that relevant, well-documented data are preferred, and they list key characteristics and guidelines to consider in assessing measure lifetime studies. However the guidelines are flexible, allowing for interviews with equipment vendors and review of manufacturer warranties or other product information as possible sources. They also allow professional judgment to be used as a data source as long as the rationale is well documented.

The guidelines require that estimations consider any factors that affect measure lifetime by at least 20%. In contrast, there is 10% threshold for energy savings, a more stringent threshold. In addition to regional or climate zone impacts, the guidelines list several potential factors that may have a substantial impact on lifetime (table C4).

Table C4. Factors that affect lifetime in RTF guidelines

Installation-related factors	O&M- and usage-related factors
Program installation method and practices	Maintenance practices
Delivery verification	Operating hours
Equipment sizing and rating	Operating conditions or practices
Remodeling prior to a measure's expected physical failure.	Occupancy changes

Source: RTF 2018

Appendix D. Interviewees by State

We interviewed each of the individuals below to provide background knowledge and confirmation of our primary desktop research. We gratefully acknowledge their contributions and note that these interviews do not imply affiliation or endorsement.

California

California Energy Commission: Chris Cavalec, Mike Jaske, Cynthia Rogers, Brian Samuelson
California Public Utilities Commission: Paula Gruendling, Jeorge Tagnipes
Future Energy Enterprises: Jennifer Barnes
Los Angeles Department of Power and Water: Armen Saiyan
Pacific Gas & Electric, Robert Kasman
Southern California Edison: Chuck Winn

Illinois

ComEd: Arturo Hernandez, Jim Fay
Illinois Commerce Commission : Jennifer Morris
Navigant : Karen Maoz
Nicor Gas: Jim Jerozal

Michigan

Consumers Energy: Theodore Ykimoff, Hubert Miller
DTE: John Boladian, Manish Rukadikar
Michigan PSC: Brad Banks, Karen Gould, Dave Walker

Ontario

IESO: Tina Nicholson
Ontario Energy Board: Valerie Bennett, Josh Wasylyk
DNV GL: Tammy Kuiken

Oregon

Energy Trust of Oregon: Fred Gordon, Jack Cullen, Spencer Moersfelder
Oregon PUC: Anna Kim
Northwest Power and Conservation Council: Tina Jawayweera
Regional Technical Forum: Jennifer Light

General Expertise

Northwest Power and Conservation Council: Tom Eckman (former)
Energy Futures Group: Chris Neme
Oracle: Richard Caperton, Charlie Buck, Marissa Uchin
Prahl & Associates: Ralph Prahl
Schiller Consulting: Steve Schiller