An Update on the Evaluation of Energy Efficiency Standards in California

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Abstract

Utilities increasingly are investigating the options of pursuing energy codes and appliance standards because of the potential they provide for significant, cost-effective energy savings. However, experience remains very limited in evaluating the impacts of programs seeking to upgrade codes. Since the late 1990s, California utilities have played a significant role in researching, proposing, and promoting Codes and Standards (C&S) to reduce loads. Savings from utility C&S programs are difficult to estimate and the absence of broadly-accepted evaluation methods for such programs has limited recognition of the California utilities' efforts. To address these gaps in methods and estimated energy savings, a California Public Utilities Commission (CPUC) evaluation began in 2007 of the statewide C&S program implemented by the major California utilities.

In 2006, California adopted an evaluation protocol for evaluating C&S programs. In 2007, we began using the protocol in the current formal evaluation, enhancing and refining it as the evaluation progressed. Accurate evaluation results are critical because potential savings are very large, and because the CPUC must properly assess savings credits for the IOU's C&S efforts. The evaluation methodology and findings and will be of significant interest to other states and utilities looking more closely at the role C&S programs can play in achieving ever-more challenging energy-efficiency targets.

This paper provides an overview of the C&S program protocol used and focuses on experience gained through the analysis. The protocol accounts for several factors, including: gross first-year energy savings from each code/standard; effects of market trends in the standard's absence; non-compliance; and the portion of savings that can be attributed to the utility efforts. For each factor, research design and methods will be described. Problems encountered and their resulting solutions will be covered in detail.

A second paper, *Determining Compliance with Appliance Energy-Efficiency Standards* (Cathers, Lee, et al., 2009), will also be presented at the IEPEC 2009. It describes the methods and challenges encountered for another component of the current C&S evaluation.

Introduction

Benefits of Codes and Standards[1]

Efficiency standards set minimum efficiency levels that new appliances and buildings must meet or exceed. Because they eliminate low-efficiency products from the market, standards have become an important mechanism for reducing energy consumption. In the 1970s, states began establishing regulatory frameworks for developing, adopting, and implementing such standards. In California, the California Energy Commission (CEC) was created and one of its regulatory roles was adoption of

[1] The terms "code" and "standard" are often used interchangeably. Most authors use "codes" when referring to building efficiency requirements and "standards" when referring to appliance efficiency requirements. In this paper, we use the terms interchangeably.

building and appliance efficiency standards. The California building standards are referred to as Title 24 standards and the appliance standards are referred to as Title 20 standards, based on their respective location in the California Administrative Code. Both the federal government and states have continued developing and upgrading their efficiency standards.

Starting in the late 1990s, California utilities began playing a significant role in researching, proposing, and promoting efficiency standards through what has become the statewide utility Codes and Standards (C&S) Program. Like other "statewide" programs, each of the IOUs has a C&S program. These individual programs provide a home within each company for funding of the program activities and also for savings claims in the IOU portfolio. One of the major program activities is funding third party research into specific code changes. The resulting research reports have generally been named Codes and Standards Enhancement Initiatives and are commonly referred to as "CASE" reports. The CEC process for proposing and approving changes to the California appliance and building standards has come to rely on these CASE reports to a large extent. Savings from the C&S Program are difficult to estimate and attribute to utility actions. Still, utilities and the California Public Utilities Commission (CPUC) are highly motivated to overcome the challenges to allow savings from the C&S Program to become another asset in the demand-side management (DSM) portfolio.

To this end, efforts have been made to estimate savings from the C&S Program and establish a regulatory process to account for them. In 2002, initial estimates suggested the Program might account for up to 10% of utilities' savings goals, while requiring utility investments of only about 0.5% of total DSM expenditures. However, the analysis was subject to several uncertainties and based on limited data. In 2006, California adopted an evaluation protocol that included a methodology for evaluating C&S Programs [CPUC 2006]. That methodology is the basis for evaluating verified savings from the Program for consideration in the regulatory process.

Because of their cost effectiveness, ability to raise efficiency in an entire market, and inherent long-term market transformation potential, utilities and other organizations nationwide are examining ways to increase efficiency standards. However, issues remain about quantifying savings they produce and attributing credit to IOUs promoting their adoption.

This paper focuses on key components of the evaluation methodology and discusses the approaches being implemented. The evaluation's final results are not yet available so this paper presents examples of how to apply the methodologies for evaluating IOU C&S programs focusing on the evaluation of appliance standards and including some highlights on key lessons learned. Though the evaluation findings and methodology are designed for the California setting, they will also be of significant interest to other states and utilities looking more closely at the role C&S programs can play in achieving ever-more challenging energy-efficiency targets

A second paper, *Determining Compliance with Appliance Energy-Efficiency Standards* (Cathers, Lee, et al., 2009), will also be presented at the IEPEC 2009. It describes the methods and challenges encountered for another component of the current C&S evaluation.

Objectives

In 2007, The Cadmus Group began using the California protocol to evaluate impacts of the C&S Program and enhance and refine the protocol as the evaluation progressed.[2] The broad evaluation objective is to provide *ex post* verified savings estimates. In the end, we will deliver quantified, verified savings and a set of recommendations for improving the protocol. These results then will be used by the

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[2] The Cadmus Group is a subcontractor to KEMA (formerly RLW Analytics, Inc.), which is the prime contractor to the California Public Utilities Commission for this evaluation.

CPUC to assess the C&S Program's contribution to the utilities' savings goals and to improve future evaluation efforts.

Protocol, Methodology, and Model

The CPUC established ambitious energy-efficiency targets for the California utilities for 2006 and beyond. In a 2004 decision, the CPUC stated: "In order to meet today's adopted goals, program administrator(s) should aggressively pursue programs that support new building and appliance standards… Only actual installations should be counted towards the savings goals." [CPUC 2004] The challenge this presented was how to determine the energy savings attributable to the C&S Program in a consistent, defensible manner.

The nature of the C&S Program and its effects require applying an impact evaluation methodology different than the approach used to evaluate typical DSM programs. Some of the reasons a different approach is required include:

- Standards are adopted and implemented by a state agency, not the utilities.
- Utility efforts influence standards adoption rather than customer behavior.
- Utilities are not the only parties that affect adoption of new standards.
- Customers do not opt to be "participants" in the standards—the standards apply to all covered products and buildings—consequently, there are no non-participants.
- Standards compliance is determined and enforced by local or state government agencies; utilities do not enforce building/appliance standards to ensure compliance.
- Natural energy-efficiency market trends affect the savings attributable to standards.
- Utility acquisition programs interact with standards.

Between 2001 and 2007, four studies were conducted to assess energy savings due to utility efforts. In the course of these studies, different aspects of the C&S Program were explored and the methodology was refined [HMG 2001, ADM 2004, HMG 2005, Khawaja 2007]. In 2006, the CPUC published a detailed program evaluation protocol based on the prior work [CPUC 2006]. The C&S Program protocol largely reflects the methodologies as it evolved from the prior studies.

The major elements of the steps in our implementation of the evaluation protocol are shown graphically in Figure 1. The process begins by determining the maximum potential energy savings that could result from each standard. After a number of adjustments are made, the net savings attributed to the C&S Program are allocated to each of the utilities supporting the Program.

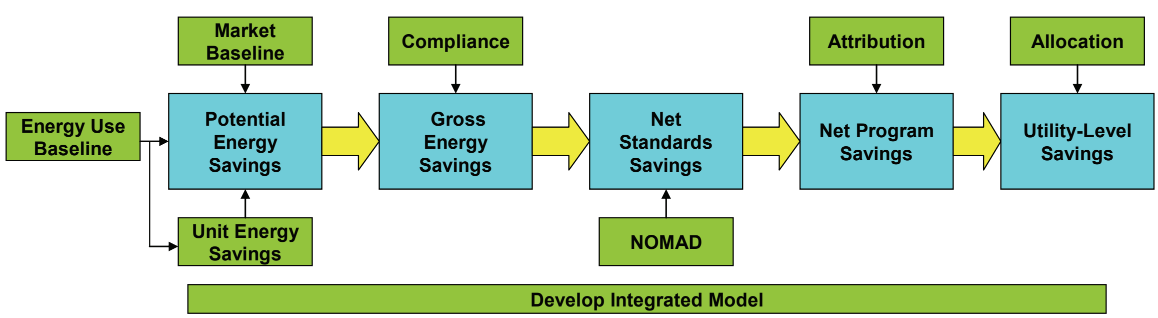

Figure 1. Evaluation Components Based on the California Protocol

Before discussing details of the evaluation process, it is useful to define the key components in the methodology.

- *Potential Energy Savings*. The impact estimate begins with each standard's potential first-year savings, defined as the unit energy savings times the total number of appliances or buildings affected in the first year. Unit savings depend on the difference between baseline energy consumption and consumption of a product or building measure meeting the standard.
- *Compliance*. Since it is likely not all products will comply completely with a new standard, the compliance rate is determined and used to adjust potential savings for the compliance level and determine the gross savings achieved.
- *NOMAD*. Naturally occurring market adoption is an estimate of what the market penetration of an efficient product or measure would have been if a standard had not been adopted. Since energy savings from these items would have occurred without the standard, they must be subtracted from the potential savings to determine the additional net savings due to the standard.
- *Attribution*. Since numerous entities may be involved in developing and adopting a standard, it is appropriate to determine how much credit is attributable to the efforts of the C&S Program. Attribution is the process of assigning some part of the credit for adoption of each standard to the C&S Program.

This paper discusses all components of the evaluation methodology except the compliance analysis. Though the basic compliance approach is similar between the Title 24 and Title 20 standards, the details of the process differ considerably. As noted above, a second IEPEC 2009 paper will review compliance analysis for the Title 20 standards while the evaluation plan describes the Title 24 compliance analysis methodology [RLW 2008].

Potential Energy Savings

This step consists of a thorough review of analyses and documentation used as the basis for estimating the savings potential for each standard. The C&S Program produced a Code and Standard Enhancement (CASE) initiative report for each standard for which savings were claimed. The CASE report, the main support document describing the estimated savings claimed by the utilities for each standard [HMG 2005] (referred to hereafter as "HMG report"), and other sources were thoroughly reviewed to validate the initially estimated potential savings. A similar methodology was applied in our analysis of the building and appliance standards, but for brevity we limit the discussion here to specifics of the appliance standards.

Per Unit Savings

Validating the per-unit savings involved assessing two specific components: baseline energy consumption (the typical energy consumption of the unit before a standard is implemented) and unit energy savings.

Baseline consumption. The baseline consumption was the basis for all energy savings estimates. There were three different methods used to calculate baseline consumption for appliances:

- standardized energy efficiency calculation for a measure that just meets the standard
- equipment metered data to determine an overall average baseline consumption
- engineering equations using clear assumptions

In all cases, we determined whether the method was applied correctly and consistently in the CASE reports. If metered data were used, we reviewed the source document to evaluate the metering methodology. If engineering equations were used, we reviewed the assumptions made about parameters such as operating hours, typical wattages, and equipment performance characteristics. In our review, we identified any discrepancies or concerns about the approach and documented them for subsequent research and possible revision.

Unit energy savings. The next step involved reviewing the estimated reduction in unit energy use due to the proposed standard. For appliances, some standards were defined in terms of a percentage savings over a baseline model; others involved adopting a third-party Tier 1 or Tier 2 efficiency level; and others involved setting specific improvements in components that would lead to a reduction in whole unit energy use.

For each standard, we attempted to replicate the initial CASE report unit savings estimates; check whether these were consistent with those reported by the utilities; and identify any discrepancies. In all cases where issues arose, we contacted the CASE report author(s) and discussed our questions and resolved any discrepancies.

Review of First-year Sales

Once the unit baseline and unit energy savings were investigated and revised as appropriate, the estimated annual sales were reviewed. This involved examining the data sources identified in the CASE reports or HMG report. We reviewed these sources to determine if they were consistent with the sales estimates reported as the basis for the potential savings estimates and all calculations were done properly. If any errors were identified, they were documented and corrections were made as needed.

Review Potential Energy Savings

The factors discussed above were then combined to calculate total potential energy savings expected for the first year of introduction of the standard. The general equation used to derive the first year potential energy savings was the following:

Potential energy savings in year 1 = unit energy savings* unit sales/installations in year 1

If any questions or discrepancies remained at this point, we contacted the CASE report author for clarification. Once the author responded, these replies were used to make any appropriate changes to update the potential energy savings in the first year of installation

Review More Recent Information; Update; Revise Potential Energy Savings

When the review of first-year potential energy savings was completed and any inconsistencies or gaps were resolved, we searched for and reviewed the most recent studies and sales data. Findings from this step were documented.

The final step in analyzing potential energy savings involved compiling all adjustments described above, determining which values should be modified, and documenting the reasons for the changes.

Naturally Occurring Market Adoption (NOMAD)

Two key terms are defined as follows:

- **Initial market penetration** represents the state of the market at the time the standard became effective in terms of the share of annual installations or purchases already meeting the requirements of the standard.
- **Naturally occurring market adoption**. NOMAD is a projection of what the annual sales or installations of items meeting the standard would have been if the standard had not been adopted. NOMAD defines the point estimate for "initial market penetration" at the time the standard becomes effective. Once the standard is in effect, the "natural market" no longer exists, but the established evaluation methodology requires that NOMAD be estimated in order to adjust the gross savings for each standard.

Methodology

Our NOMAD estimates are based on a Delphi process using expert opinions to define a market diffusion curve. Each expert is asked to participate in two data collection rounds. In the first, the expert defines the parameters of a typically S-shaped Bass curve (described later) for each standard using an online application and provides comments to explain his/her reasoning.

A second round is used following guidelines established for the Delphi method which is a group communication process among a panel of geographically-dispersed experts[3]. Its elements include (1) structuring of information flow, (2) feedback to the participants, and (3) anonymity for the participants. The Delphi method permits information sharing, while minimizing domination of the group process by especially vocal or intimidating individuals.

To capture the benefits of a Delphi process, the second data collection round was implemented as follows. An online application (which is described in the Implementation section below) shows all experts' Bass curves plus a simple average of all curves on a single graph. In addition, all the first round comments are shown. To preserve confidentiality, curves and comments are not identified by author. Next, the experts are given an opportunity to stay with their original estimate, agree with the average estimate, or define a new estimate. In this way, differences are clarified and, ideally, consensus emerges.

Since NOMAD is an estimate of what would have happened in a market if a particular standard had not been adopted, there is a need to model the adoption or diffusion of each energy efficient technology. We chose to use the diffusion model developed by Frank Bass since it has been shown to be a useful construct for product forecasting and technology diffusion. There is an extensive body of literature on the Bass model and on technology diffusion as this is an area of great interest to many consumer product and technology companies. This approach was used successfully in the prior Codes and Standards study (Khawaja, Lee 2007) and we are applying it again in this evaluation.

[3] RAND Corporation. 1958. On the Epistemology of the Inexact Sciences, AD0224126, Santa Monica, California.

The Bass curve was used to characterize naturally occurring adoption rates. The standard Bass curve can be represented by the following equation:

$$F(t) = \frac{1 - e^{-(p+q)t}}{1 + (q/p)e^{-(p+q)t}}$$

Where F(t) = the cumulative fraction of adopters,
p = coefficient of innovation,
q = coefficient of imitation, and
t = elapsed time

The p coefficient captures the effect of consumers who are not influenced by the behavior of others and q captures the effect of consumers who are influenced by prior adopters.

For this study, the most critical part of the curve to estimate accurately was during the initial years following introduction of the efficient measure/ appliance because the S-shaped curve can provide more realistic estimates of naturally occurring market adoption rates during the years when products gradually increase their market shares. Prior studies had used linear curves to represent NOMAD. Typically, the effect of going from a linear curve to an S-shaped curve for NOMAD is to reduce penetration rates in the early years, but to increase them over the linear estimates in later years.

It was essential to determine a start date for the NOMAD curve for each appliance or measure. We selected a start date using an iterative process, beginning with a literature review for each item and relying heavily on information presented in the relevant CASE report and from experts participating in our analysis to confirm or modify proposed start dates. The start date for a market adoption curve represents the point in time when a new technology was introduced. We defined this as the year when products using the new technology were offered in the market. Sales volume provides clear evidence that products are offered and that adoption has begun.

We took a final step to adjust the NOMAD estimate to account for the effects of prior investor owned utility (IOU) DSM programs. While such programs operate they can have a significant effect on market penetration of efficient appliances or measures, shifting the market adoption curve upward. Such effects should be accounted for in DSM program evaluations and removed from the apparent NOMAD trend. In our approach, program effects are included in the initially estimated NOMAD curves since the actual observable market up until the time that a standard is adopted includes any impact that utility programs have had. Our experts agreed that they are best able to estimate the market adoption curve starting with the market that existed up until the point in time when the standard became effective. We then adjusted the NOMAD curve *downward* to take out the effects of these IOU programs.

Implementation: Putting Theory into Practice

The two main steps in implementing the Delphi process were recruitment of experts and data collection.

Recruitment of Experts. In the recruiting process, we first considered which perspectives and organizations should ideally be requested to provide their inputs. The goal is to have objective input based on direct knowledge of markets and knowledge of the regulated products / technologies. One way to test for the presence of bias is to target individuals from a range of organizations. Accordingly, the target list included representatives of manufacturers, industry consultants, the CEC, and IOUs. Two primary sources were tapped to develop a master list of candidates: the CEC transcripts and materials from meetings where each standard was on the agenda and the IOU CASE reports.

With these preparations completed, we contacted each person on the master list using email messages and telephone calls to persuade the candidate to participate. We had the most success in recruiting manufacturers' representatives/employees and industry consultants.

Data Collection. Traditional methods of estimating the Bass curve parameters are to use values from curves for similar products, rely on market research, or apply expert judgment. We selected an innovative approach that relied on inputs from our experts using a visual tool developed specifically for this purpose that was housed at an interactive Web site. This visual approach maximizes the efficacy of data collection, as it provides direct feedback, is more intuitive, and is appealing to use.

The Web site introduces the process and the overall approach, and explains the inputs and parameters of the market-specific adoption curve. Application developers on our study team customized a JavaScript charting tool to create the data collection tool. This application includes an interactive display that the respondent adjusts to select the innovative and imitative parameters used in the Bass model equation. For purposes of this exercise, we modified the terminology and referred to these parameters as "leading" and "following" behavior, respectively.

Example: Commercial Dishwasher Pre-Rinse Spray Valves

First round input. Eight individuals provided first-round market adoption estimates for efficient pre-rinse spray valves. This included three industry consultants, two people from the Food Service Technology Center, a manufacturer, a technical expert from Lawrence Berkeley National Laboratory, and a program expert from East Bay Municipal Utility District. Three had gained direct knowledge of the market when they worked on a California Urban Water Conservation Council (CUWCC) program installing efficient valves between 2002 and 2005.

Experts provided their inputs defining a market adoption curve using the graphical application and their comments regarding factors that determined their estimates. Six of the estimates were generally similar and could be viewed as a near-consensus among the majority. The other two were significantly outside this cluster, so we examined them in some detail.

Second Round input. We invited all experts to return to the online application to review the first round inputs and consider whether any change to their inputs was warranted. For the second round, all first round inputs and an average curve were shown to the returning expert as well as all the comments (without identification).

Figure 2 summarizes the results of the NOMAD evaluation for pre-rinse spray valves. From top to bottom of the legend, the data shown include:

- Avg Round 1 Inputs represents the average based on all eight initial inputs.
- Avg Selected Inputs represents the average when the two first-round outliers are excluded and the second round input for those two experts who provided it are included.
- Bass Curve Fit is the curve based on selecting the three curve parameters that generate the best fit; the curve is virtually identical to Avg Selected Inputs curve.

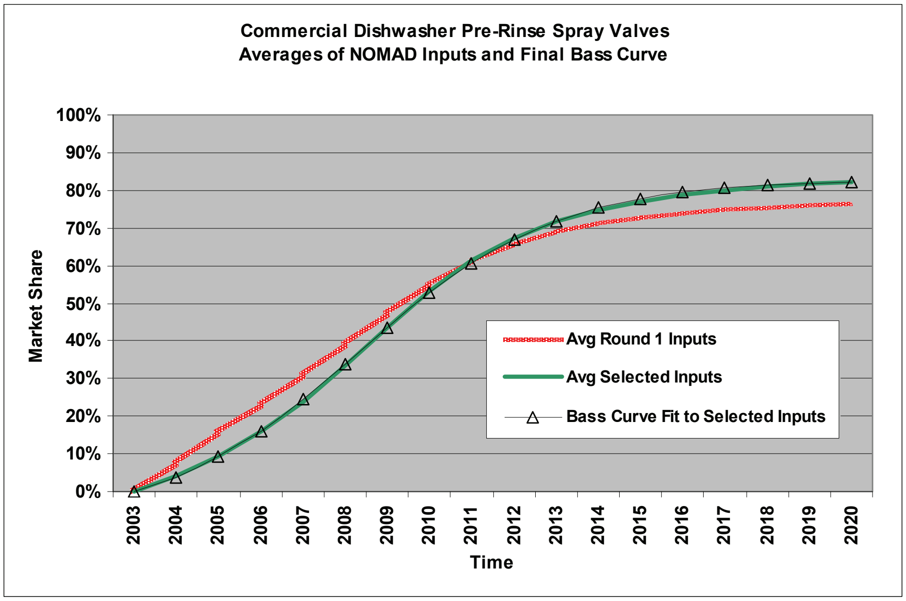

Figure 2. Summary of NOMAD Results for Pre-Rinse Spray Valves

We generated a Bass curve that best fit the selected average curve. The parameter values for that curve were then available to generate a NOMAD curve for adjusting pre-rinse spray valve gross savings to estimate net savings due to the standard.

Attribution

Attribution is the process of determining the credit due the C&S Program for its contribution to the adoption of California building and appliance energy-efficiency standards. Net program savings are the product of an attribution score (between 0% and 100%) and the net standards savings derived as described above.

An attribution methodology had been developed in a prior study [Mahone 2005]. After carefully reviewing the study and consulting with CEC staff and other stakeholders, we revised the methodology to reduce the possibility of bias in the determination of credit, to eliminate some ambiguities and potential redundancies, and to make awarding of credit for promoting standards adoption consistent with CEC criteria for standards adoption.

Attribution Methodology

In the revised methodology, the C&S Program will receive credit for its contributions in three *factor areas*:

1. Development of compliance methods and techniques for estimating energy savings.
2. Development of technical and cost information and language for the standard
3. Demonstrating feasibility of the proposed standard, including market readiness and responding to stakeholder concerns.

A complete description of the factor areas and an illustrative list of activities for which the C&S Program can receive credit are available in the attribution methodology description at the CPUC website: http://www.energydataweb.com/cpuc .

The C&S Program attribution score for a standard will be calculated as follows:

1. A *factor weight* for each factor area will be estimated. The factor weight indicates the percentage of combined stakeholder resources dedicated to addressing each factor in the development and adoption of the standard. The factor weights assign greater weight to contributions in areas in which utilities expended greater effort. The weights will be allocated so they total 100% across the three factor areas.
2. A *factor score* (0% to 100%) will be determined in each factor area indicating the C&S Program's contribution in the area. Factor scores will be determined using information in public documents and obtained in interviews with stakeholders. The factor scores will be determined by a team of evaluation staff who has reviewed the documentation and summary information.
3. The C&S Program attribution score for each standard will be the sum of the products of the score and weight for each factor. The final attribution score (0% to 100%) represents the weighted contribution of the Program toward adoption of each standard.

Data Collection

To estimate the variables in the attribution model, we have collected information from a variety of sources, including public documents and surveys and interviews of stakeholders. Information about the allocation of resources between the factor areas in the development of a standard was obtained in a survey of a small number of stakeholders closely involved in the adoption of the standard. In addition, we have carefully read the Code Change Proposal, the CASE report, transcripts of CEC workshops and hearings, oral and written comments to the CEC, and the Code Change Theory reports for each standard to identify C&S Program and other stakeholder contributions. Information about contributions in these sources was entered into Excel spreadsheets for subsequent analysis. Finally, we will also conduct telephone interviews with a small number of stakeholders to discuss activities of the C&S program that were important to the development of the standard but went undocumented. For instance, some important stakeholder concerns may have been resolved outside of public view.

Estimation of Factor Weights and Scores

After collecting information from these data sources, Cadmus will estimate the factor weights and scores for each standard. The *factors weights* will be estimated using the survey responses to the question about resource allocation. The *factor scores* will be determined using information about the C&S Program and other stakeholders' contributions to standards adoption from the other sources. The factor scores will be determined using a well-defined, documentable, consistent, and repeatable method; based on specific C&S Program actions leading to standards adoption; and determined by disinterested, third parties.

Summary

Lessons Learned

Major lessons learned about applying the methodologies described in this paper are summarized in Table 1.

Table 1. Lessons Learned

	Worked Well	More Challenging
Potential Energy Savings		• Missing documentation of revisions to savings claims between CASE reports and studies used to justify utility claimed savings
NOMAD	• Updated Web-based application and database worked flawlessly to capture expert inputs • Second round of expert input. Although total participation was limited, experts that returned for second round typically reacted to estimates and comments of other experts. Responses included additional support for their position but also some shifts to more central positions / consensus.	• Gaining participation of experts especially for specific standards and from specific segments • Obtaining market data from prior years. Ideally, data on market share of efficient products is tracked throughout (pre and post adoption)
Attribution		• To develop inputs for the attribution model retrospectively because of fading memories and lost records. Ideally the process is defined and data are collected throughout (pre and post adoption)

Conclusions and Implications

Evidence to date from California's C&S Program suggests that utilities' standards advocacy efforts have the potential to produce significant energy savings for a relatively modest utility expenditure. In the 2004-05 period, less than 0.5% of the utilities' energy-efficiency program expenditures went to the C&S Program but they potentially produced about 10% of the net energy and demand savings estimated for all their DSM programs.[4]

Because of this large potential, it is important to encourage utilities to continue targeted efforts to upgrade efficiency standards. On the other hand, remaining uncertainties and difficulties in calculating verified C&S Program savings suggest that diverse utility energy-efficiency programs should continue to play a significant role in the overall efficiency portfolio. The CPUC has taken significant steps toward resolving this dilemma and striking an appropriate balance.

Several states and utilities have expressed an interest in the proper role for utilities in upgrading efficiency standards and how their efforts should be encouraged and incentivized. We believe findings from prior and current research provide a solid foundation for future efforts to appropriately calculate energy savings attributable to new standards and to determine the proper allocation of credit to utilities. The ongoing evaluation described here will add significantly to the analytic capabilities developed in the past. With a reliable, credible method for analyzing energy savings from standards and allocating credit to utilities, utility codes and standards programs should become a viable component of energy-efficiency program portfolios throughout the country.

Though this paper focuses on the issue of determining how much credit utility programs should receive for their efforts to advance energy-efficiency standards, accurately estimating savings from efficiency standards should be important to all organizations involved in proposing or developing such standards; this includes state and federal agencies and various advocacy groups. The authors believe that many of the insights from the methods developed to evaluate the California utilities' C&S Program are relevant to assessments of other investments in standards upgrade processes.

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[4] Under CPUC rules, the utilities' credit from these efforts during the 2006-08 timeframe is 50% of verified savings, with the adjustment made because of uncertainties in the original approach used to estimate claimed savings.

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