Integrating Energy Efficiency into Utility Load Forecasts

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ABSTRACT

Efficiency Vermont's efficiency programs are being integrated into Vermont's utility planning for the first time, and are influencing utility decisions about the need for new generation and transmission investments as a result. Because load forecasts form the foundation for utility investment decisions, the forecast method is an important issue. The industry's approach to forecasting load has changed little in response to the presence of long-term energy efficiency programs in states such as Vermont. The accepted method for incorporating energy efficiency resources into load forecasts is simply to subtract the efficiency from the load. Although this is a convenient assumption, the reality is more complex. This method over estimates program savings impacts as some of the efficiency impacts are already embedded in the load forecast. Adjusting the load forecast for efficiency savings in this manner can result in a long-term demand forecast that is too low.

In states like Vermont, where higher levels of energy efficiency investment are expected to reduce utility loads and avoid future infrastructure investment, an integrated forecasting approach is important to continue making good investment decisions in both efficiency programs and system infrastructure. This paper discusses the roots of the forecasting challenge facing Vermont and the nation and proposes an integrated, collaborative approach to forecasting both utility loads and programmatic efficiency savings.

Introduction: A LEED Gold Building's Effect on Utility Load

In 2007, the University of Vermont (UVM) completed construction of a new LEED Gold Certified building, the Dudley H. Davis Center. This building was the first student center in the nation to achieve LEED Gold for new construction, and UVM worked closely with its electric utility, the Burlington Electric Department (BED), throughout the design and construction process to reduce electrical energy use. As a result of this collaboration, BED was able to claim the electrical energy savings associated with the building for its efficiency programs and UVM benefited from BED's incentive payments and building science expertise.

As BED's electricity trader and resource planner, one of the authors (Enterline) was charged with planning for and purchasing the right amount of electricity for the Department, and the 186,000 square foot Davis Center posed an interesting question. "If the energy efficiency savings from the Davis Center are subtracted from the load forecast during the planning process, then why did BED's metered load grow?" The answer in this case was self evident; the building was brand new. However, this experience led to the thinking that is the subject of this paper. How can utilities and efficiency programs work together to accurately forecast loads in the presence of aggressive energy efficiency programs?

The Load Forecasting Challenge

One of the more complex tasks facing energy demand forecasting is appropriately accounting for the impact of utility-sponsored energy efficiency programs. These programs seek to reduce energy usage by encouraging adoption of more efficient technologies through cost subsidies and other market development strategies. What complicates the forecasting task is that some of the impact of these programs is already embedded in the data used to estimate the forecast model. And within an end-use (bottom up) load forecasting framework like the one used in Vermont, savings from Efficiency Vermont's programs are partly incorporated in the end-use efficiency projections, which are used to build up the load forecast itself. Federal appliance efficiency standards, tax credits, and "naturally occurring" efficiency gains further complicate the forecasting problem. As a result, estimation of efficiency savings can no longer be made in isolation of the load forecasting process.

The problem of underestimating load is more likely where there has been an active efficiency program over several years. This is the case in Vermont where Efficiency Vermont has significantly reduced customer usage through a range of residential and commercial efficiency programs. For the purposes of load forecasting, Vermont assumed that Efficiency Vermont would be funded to continue developing and implementing efficiency programs throughout the forecast horizon (20 years). As a result, Vermont's electric utilities are grappling with how best to incorporate historical and future efficiency program savings into their load forecasts. Why? The accuracy of the load and efficiency forecasts have a direct impact on system planning, revenue projections and rate making, all of which are essential elements of a utility's business.

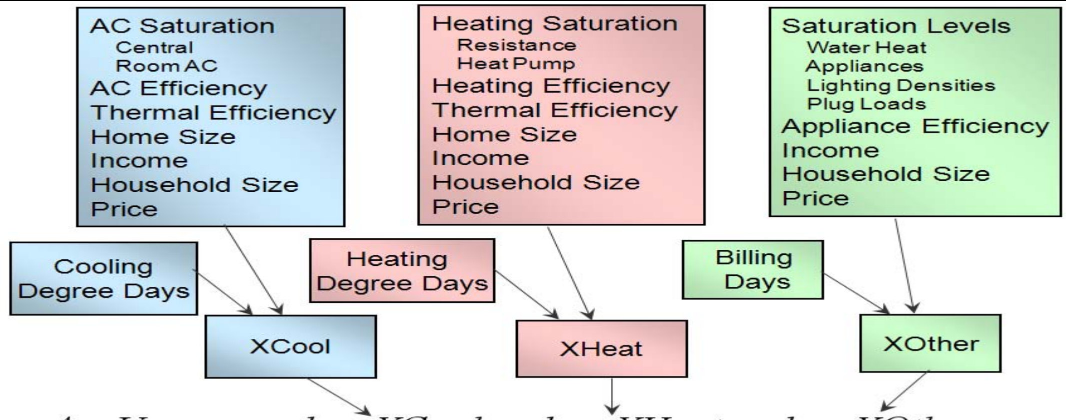
Long-Term Load Forecasting Methods

Over the long-term, energy demand is primarily driven by economic activity, weather, and energy prices, and is also influenced by appliance and HVAC[1] purchase decisions and improvements in building thermal shell integrity. During the late 1970s and early 1980s there was significant effort to develop end-use models that explicitly accounted for appliance purchase decisions and resulting end-use saturation and efficiency trends. The Energy Information Administration's (EIA) Annual Energy Outlook (AEO) is based on such an end-use model known as NEMS (National Energy Modeling System). Through the 1980's and 1990's many utilities developed end-use forecasts using the Electric Power Research Institute's (EPRI) end-use models, REEPS (Residential End-Use Planning System) and COMMEND (Commercial End-Use Model). While the end-use models provided a wealth of detail information, the models proved to be difficult to implement and costly to maintain.

More recently, utilities have been moving to a less complex modeling approach that combines end-use information into an econometric modeling framework. The approach, known as a Statistically Adjusted End-Use Model (SAE Model), leverages end-use information developed as part of the EIA's annual energy forecast. Using the AEO forecast database, end-use saturation and efficiency trends are developed for sixteen end-uses (including miscellaneous) for eight census regions. End-use saturation projections are then modified to better reflect the service area using utility and other regional appliance saturation survey data.

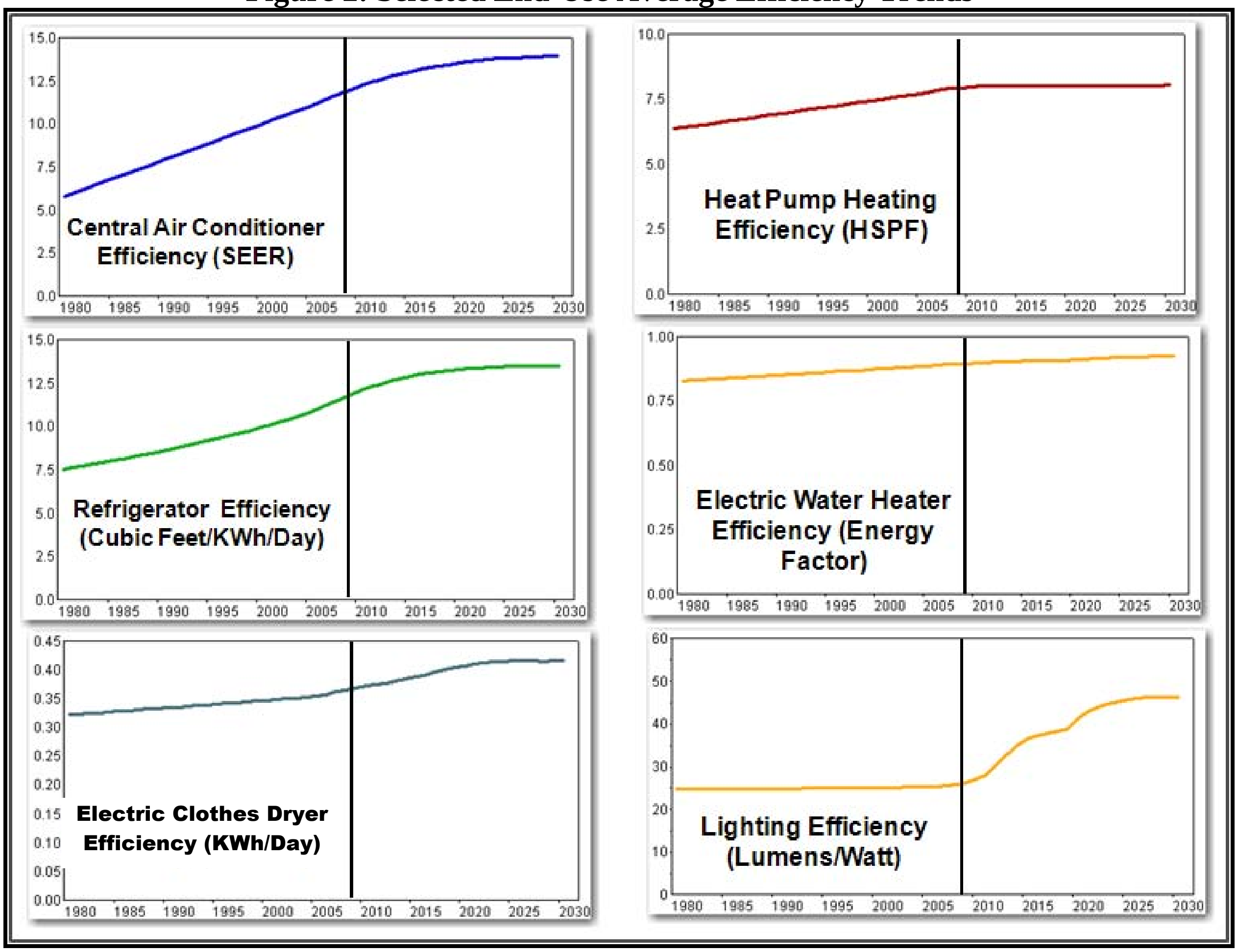
[1] HVAC stands for "Heating, Ventilating and Air Conditioning.

Figure 1: SAE Model Framework[1]



$$AvgUse_m = a + b_c \times XCool_m + b_h \times XHeat_m + b_o \times XOther_m + e_m$$

Figure 2: Selected End-Use Average Efficiency Trends[2]



For the Vermont utility forecasts, historical and projected residential end-use saturations are adjusted to reflect a state level appliance saturation survey conducted in 2005 by KEMA, and historical saturation rates developed as part of Burlington Electric's triennial residential appliance saturation survey. Including miscellaneous, the SAE model incorporates saturation and efficiency trends for sixteen end-uses.

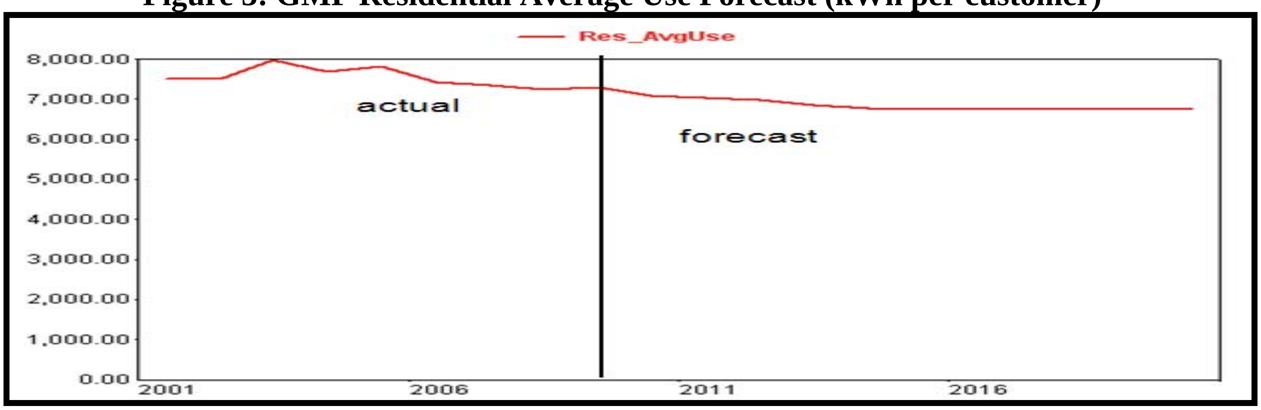
End-use saturation and efficiency data are used in constructing a monthly cooling variable (XCool), heating variable (XHeat), and other use variable (XOther). The constructed variables incorporate the other factors that drive monthly usage including weather conditions, price, and economic activity. The end-use variables are based on logic developed from the end-use modeling framework. The constructed end-use variables are then used in estimating monthly average use or sales regression models. Figure 1 shows the general model framework.

End-use efficiency trends are explicitly incorporated into the constructed SAE model variables; as end-use efficiency improves forecasted average use or sales declines. Figure 2 depicts end-use efficiency trends for several major residential end-uses.

These end-use efficiency trends reflect past purchases, expected technology option costs, energy prices, and new end-use standards and investment credits resulting from recently passed federal legislation As a result, there is significant efficiency built into the long-term forecast before adjusting further for utility sponsored efficiency programs.

Figure 3 shows the SAE residential average use forecast for Green Mountain Power (GMP), the second largest utility in Vermont, prior to adjustments for state funded efficiency program savings. Note that the average use has been declining since 2005, and despite relatively strong miscellaneous load growth, average use is expected to continue to decline through 2015. This decline is a result of new end-use efficiency standards (particularly residential lighting standards), available tax credits for efficiency improvement investments, and natural occurring efficiency gains due to falling appliance costs and higher energy costs.

Figure 3: GMP Residential Average Use Forecast (kWh per customer)[3]



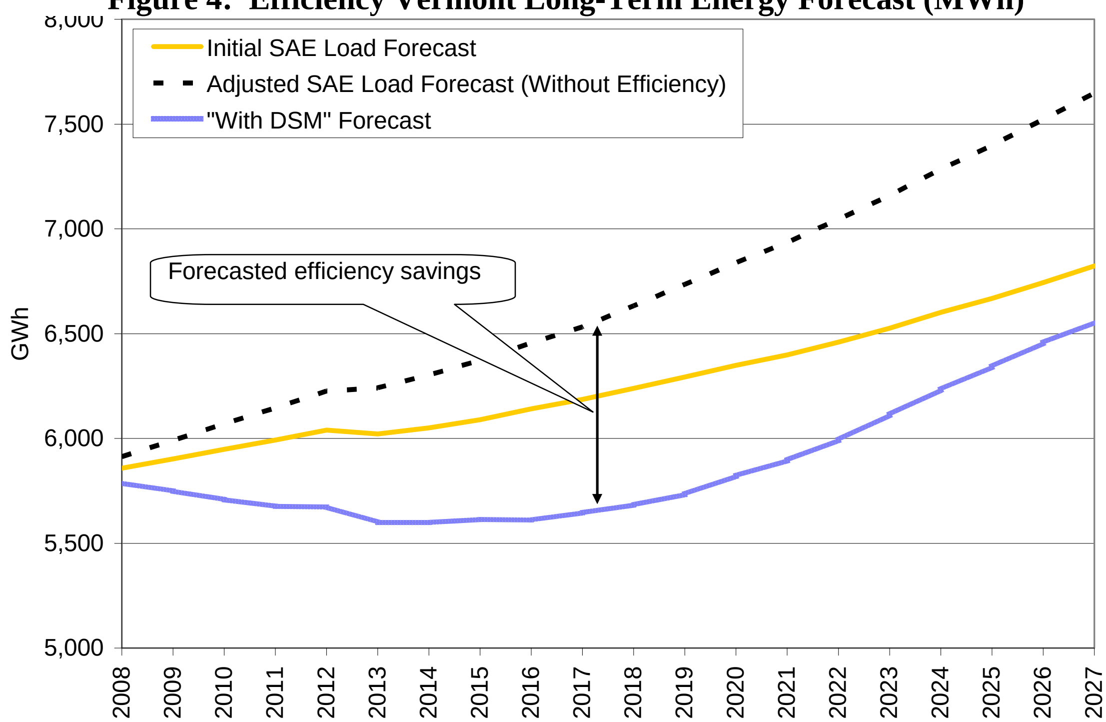
In developing the final sales forecast, sales are further adjusted for Efficiency Vermont program savings within the GMP service area. The difficult issue is identifying how much of the program savings are already captured by the forecast.

Impact of Energy Efficiency Programs on the SAE Load Forecast Model

On a dollars per capita basis, Efficiency Vermont runs one of the largest efficiency programs in the country. The strong downward trend in average usage can partly be attributable to this effort. A similar trend can be seen in commercial average usage. Many utilities across New England have also been engaged in active efficiency programs. Much of the specific activity of Efficiency Vermont and the more generalized impact of utilities across New England are captured in the estimated SAE sales forecast models.

Efficiency Vermont recognized this dynamic in its 2009 forecast of energy efficiency, and made a reasonable upwards adjustment to the baseline SAE forecast to account for historical efficiency savings embedded in the SAE forecast.[4] The adjustments were based on a simple regression model that relates historical savings to program expenditures. The model was then used to adjust the forecast upwards by applying the estimated expenditure coefficient to historical and forecasted program expenditures. The baseline forecast was also adjusted for stronger market-driven penetration of efficient lighting than that assumed by EIA. A "With DSM" load forecast was calculated by subtracting historical and future DSM savings projections from the adjusted baseline forecast. Figure 4 shows the initial SAE load forecast, the adjusted SAE load forecast, and the With DSM forecast.

Figure 4: Efficiency Vermont Long-Term Energy Forecast (MWh)[5]



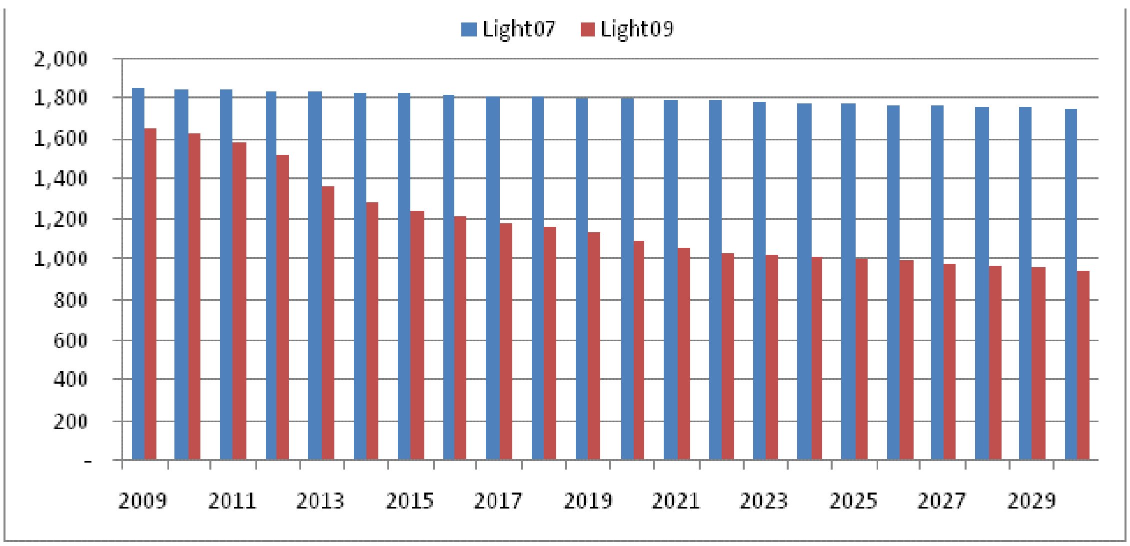
The approach used to generate the "With DSM" forecast is relatively simple and is still based on the historical practice of subtracting the forecast of energy efficiency savings from the load forecast. We propose a more integrated approach that incorporates the impact of efficiency programs using the SAE modeling framework itself. As described in the next section, the method entails changing the end-use efficiency path based on the expected impact EE programs have on specific technology adoption and using the resulting new efficiency path to drive the SAE forecast.

We have just shown how Efficiency Vermont adjusted the final SAE load forecast for the impact of efficiency programs. However, the impact of efficiency programs can be more easily and accurately captured within the SAE method itself if a common understanding of the method is established. Efficiency programs are captured in the SAE forecast model in two ways. First, the forecast model is estimated using actual sales data; the impact of the efficiency programs are thus partially captured in the regression model coefficients. Second, appliance and weatherization purchases throughout New England have partly been influenced by utility DSM programs. Appliance purchase data used by EIA in updating the annual energy forecast incorporate the impact of these programs.

For example, this impact can be seen in EIA's residential lighting usage projections. Lighting has been by far the largest targeted residential end-use. For many utilities lighting efficiency programs represent as much as 80% of residential efficiency program savings. Over the last three years, EIA has significantly reduced lighting use per household forecast largely as are result of utility lighting programs and expected impacts of future lighting efficiency standards. The lighting usage trend is incorporated as a driver in the constructed SAE Other Use variable. Figure 5 compares EIA's lighting use per customer forecasts for the 2009 and 2007 AEO forecast.

If the EIA's lighting forecast is taken as the baseline condition of the lighting stock, then the question for Efficiency Vermont in this context is, "How much more can lighting efficiency programs be expected to drive down lighting energy use in Vermont?" As we discuss in the next section, this is not the only (or even the most important) question that efficiency programs are concerned with.

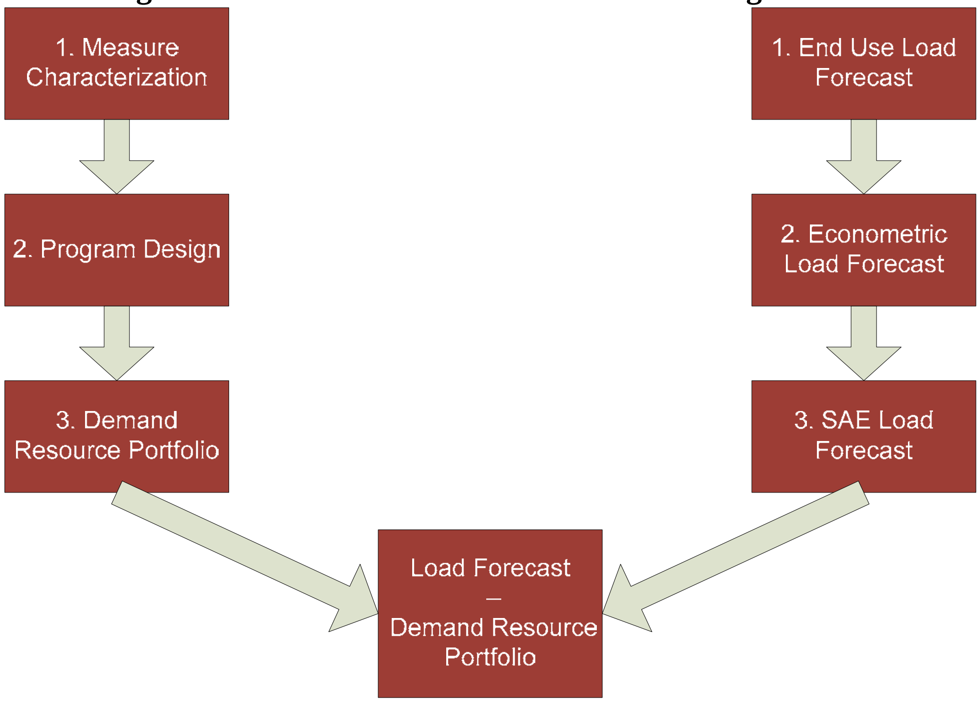
Figure 5: EIA New England Residential Lighting Forecast (kWh/year)[6]



Integrating Efficiency Program Savings into the Load Forecast in Concept

The approach that has been used for integrating Efficiency Vermont program savings into the long-term energy forecast is similar to that used by most utilities. The utility forecasting group develops a forecast independent of EE savings estimates. The forecast is then adjusted downwards for expected savings from future efficiency programs developed by Efficiency Vermont. Figure 6 shows the shows the current forecast process.

Figure 6: Vermont's Current Load Forecasting Process



This process is essentially a combination of two separate methods, one designed for measuring EE savings and one designed to forecast electricity use. The load forecast is estimated using the SAE modeling approach while the EE savings are estimated using engineering estimates of end use technologies. Both of these methods are well established in Vermont's regulatory framework. The problem is that when the EE savings estimates are subtracted out of the SAE based forecast, the energy and demand forecasts are too low as the SAE model already account for some of the efficiency savings. This problem is not unique to Vermont. It is a forecasting issue for numerous utilities with active efficiency programs.

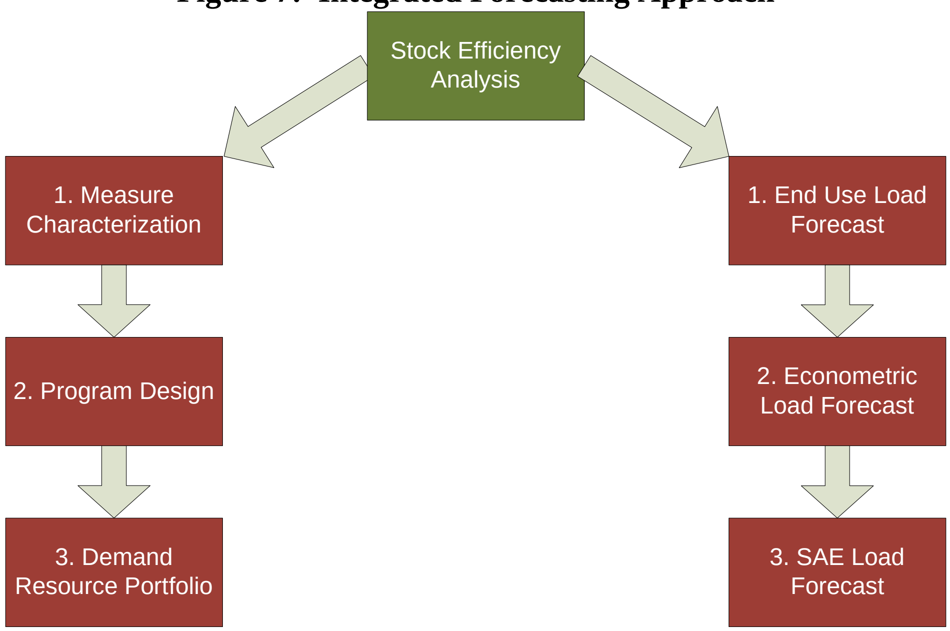
The difference between the methods used to forecast efficiency savings and the methods used to forecast utility loads comes down to ***attribution***. EE forecasting methods primarily try to answer the question, "How much energy saving consumer purchase behavior can be attributed to the efficiency program or incentive?" As a result, efficiency forecasting not only focuses on end use energy efficiency trends, but also places emphasis on the concepts of baseline energy use, customer free ridership, and customer spillover.

By contrast, utility load forecasting methods have historically been unconcerned with attribution. Instead, they are focused on answering the question, "When does the load grow to the point where system infrastructure improvements are necessary to maintain system reliability?" Free-ridership and spillover effects are not accounted for, and the utility's concept of baseline energy use is different. Baseline energy use from a utility's perspective is primarily concerned with the present day efficiency of the ***appliance stock*** while the efficiency program's concept of baseline is primarily concerned with consumer purchasing and usage behavior surrounding ***individual appliances.***

Although the emphasis is different, the goal of both energy efficiency and load forecasters is the same; accuracy. Furthermore, both forecasting methods are bottom-up modeling approaches that require a detailed knowledge of the existing end-use appliance stock and what kind of efficient technologies are entering the market. The question that unites the two forecasting processes is, "What technologies are likely to be entering the marketplace over the forecast period and how fast are they expected to penetrate the appliance stock?" This question can be addressed by analyzing appliance stock efficiency trends using the same approach that the SAE forecasting method employs.

The inputs needed to conduct appliance ***stock efficiency analysis*** are already a part of the efficiency forecaster's measure characterization and screening process, just as they are already a part of the load forecaster's SAE process. These include end-use efficiency trends, past purchase behavior, expected technology options and costs, and new end-use standards. As a result, stock efficiency analysis can be a beginning step for both the energy efficiency and the load forecast.

Figure 7: Integrated Forecasting Approach



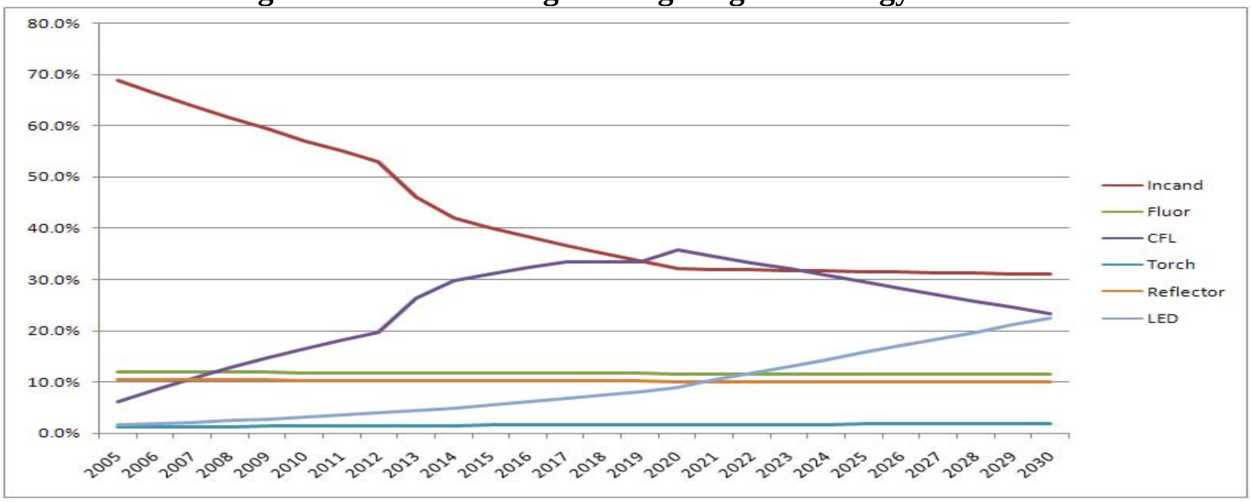
In fact, it is an ideal opportunity for energy efficiency and load forecasting professionals to collaborate. The efficiency professional's deep knowledge of individual technologies, markets, and pricing can improve the inputs to the utility load forecaster's model. And the utility load forecaster's view into the future utility loads can help the efficiency professional to prioritize and target efficiency dollars toward the end use technologies that are having the most impact on the utility's load.

The outcome of the integrated forecasting approach in Figure 7 is two different forecasts that have a common root but have two distinctly different purposes. The SAE load forecast would be used by utilities for system planning purposes while the efficiency savings forecast for the demand resource portfolio would be used to determine attribution for claimed savings purposes.

Integrating Efficiency Program Savings into the Load Forecast in Practice

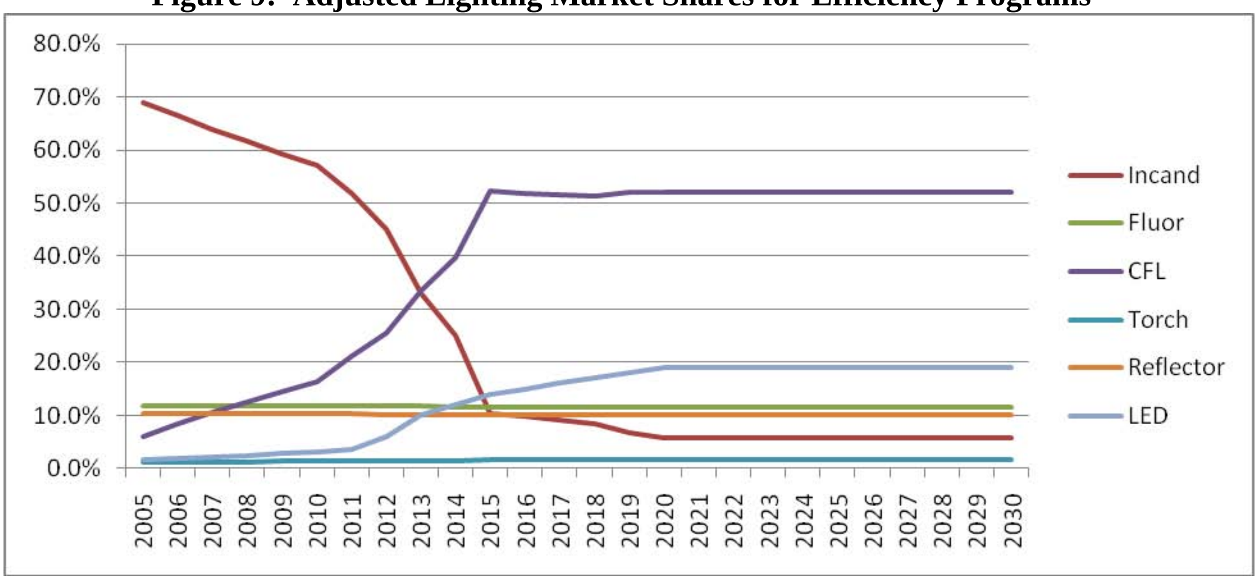
Residential lighting provides a good example as to how efficiency programs can be integrated into the load forecast. Behind the EIA lighting end-use sales projections is an assumed market penetration path of competing lighting technologies. In the residential SAE model, the primary competing technologies are incandescent lighting, compact fluorescent lighting (CFL), and light emitting diode (LED) lighting. The baseline projection of these technologies are driven by number of fixtures, relative cost, energy usage, price, and efficiency standards. Costs and wattage per lumen output of the competing technology change through the forecast period as a result of future lighting standards. Figure 8 shows the baseline technology market share projections.

Figure 8: EIA New England Lighting Technology Shares[7]



Lighting efficiency programs reduce the consumer's CFL and LED costs and in turn drive faster adoption of these technologies. This results in larger market shares for CFLs and LEDs as depicted in Figure 9:

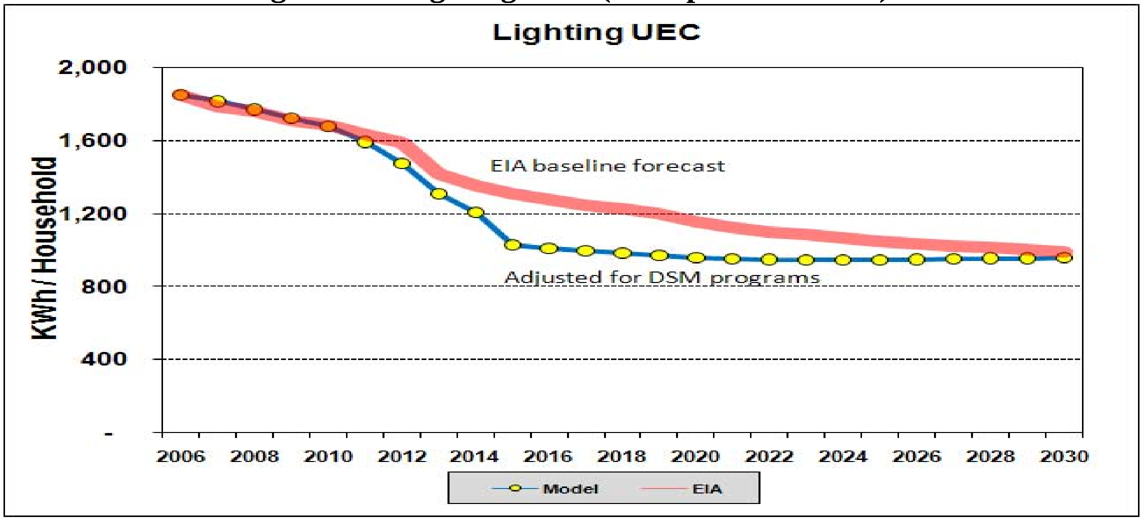
Figure 9: Adjusted Lighting Market Shares for Efficiency Programs[8]



As a result of the efficiency programs, higher CFL and LED market shares (and lower incandescent lighting share) drive lighting usage downward. Figure 10 compares EIA's lighting

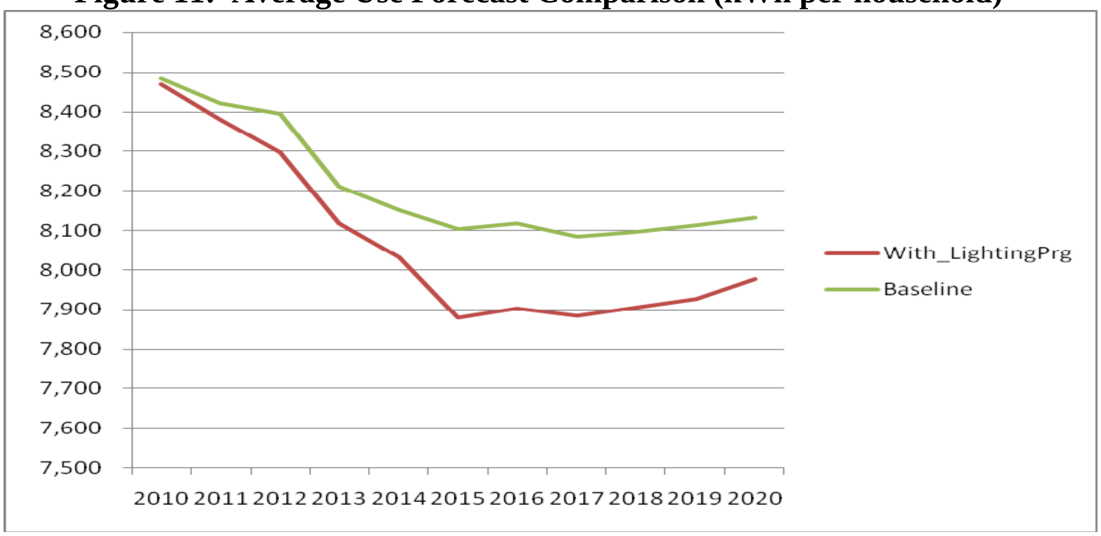
Unit Energy Consumption (UEC) forecast with a lighting UEC forecast adjusted for DSM program impacts.

Figure 10: Lighting UEC (kWh per household)[9]



The SAE model incorporates the lighting UEC forecast. As a result of the efficiency program, long-term residential average use forecast is also lower as shown in Figure 11.

Figure 11: Average Use Forecast Comparison (kWh per household)[10]



Conclusions

Because long-term forecasts are a key input into the utility planning process, it is critical to appropriately integrate energy savings from utility efficiency programs into the forecasts. Too often, the long-term energy and efficiency savings forecast are done in isolation of each other and are only integrated at the end of the forecast process. In an end-use modeling framework, this potentially results in "double counting" program savings and a long-term energy and demand forecast that is too low. This is particularly an issue where there have been active and ongoing efficiency programs.

Efficiency Vermont recognized this problem in developing the recent long-term DSM savings and state energy forecast by incorporating relatively simple adjustments to the baseline energy and demand forecast. Future state utility forecasts should focus on integrating projected efficiency program savings at the outset of the forecasting process using the SAE modeling framework.

Stronger collaboration between forecasting and DSM groups is critical. The efficiency professional's deep knowledge of individual technologies, markets, and pricing can improve the inputs to the utility load forecaster's model. In turn, the load forecaster's understanding of future energy and demand needs can help the efficiency professional prioritize and target efficiency dollars toward the end use technologies that have the most significant impact on the utility's loads.

References

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[2] US Energy Information Administration. 2009. *Annual Energy Outlook;* US Energy Information Administration. 2005. *Residential Energy Consumption Survey (RECS);* and Itron Inc. 2009. *Internal Company Analysis*

[3] Itron Inc. 2009. *Internal Company Analysis*

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[5] Efficiency Vermont et. al. 2009. Forecast 20: Electricity Savings in Vermont from 20 Years of Continued End-Use Efficiency Investment, Figure 1, Page 5

[6] US Energy Information Administration. 2009. *Annual Energy Outlook*

[7] US Energy Information Administration. 2009. *Annual Energy Outlook*

[8] US Energy Information Administration. 2009. *Annual Energy Outlook;* and Itron Inc. 2009. *Internal Company Analysis*

[9] US Energy Information Administration. 2009. *Annual Energy Outlook;* and Itron Inc. 2009. *Internal Company Analysis*

[10] Itron Inc. 2009. *Internal Company Analysis*