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Shining the Light on
Smart Grid Investments:
A Duke Energy
Case Study

Note: This paper documents an independent case study analysis of smart grid implementation issues at Duke Energy, Indiana. Duke Energy did not fund or participate in the study and any conclusions drawn from the study do not necessarily reflect Duke Energy views.

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INTRODUCTION

The recently announced $3.4 billion in federal funds designed to hasten smart grid implementation has refocused attention on this transformational technology which, in all of its manifestations, is likely to cost between $1 to $2 trillion over the next several decades. Media information on the smart grid is overwhelmingly positive with descriptions of self-healing electric networks, automatic outage notification, cell-phone directed home area networks that control appliances reducing electricity costs and so on.

Beyond the hype; however, utilities and state agencies are required to consider costs, benefits and strategies appropriate for smart grid expenditures. These investments, like other utility investments, are required to be cost effective.

Pilot programs are useful in evaluating many features of utility smart grid implementations; however, they provide limited support in determining peak period load savings for the entire utility service area over time. The ability to evaluate costs and benefits over time is especially important with these investments because smart grid initiatives require years to complete and benefits of the investments accrue largely in the future. However, many factors other than smart grids are likely to influence peak hour electricity use in future years; some of these factors can have potentially significant impacts on smart grid savings projections.

For example, as appliances, especially air conditioners, become more efficient as a result of appliance standards, retirement of existing air conditioners and new construction standards, the benefits attributable to smart grid programs are reduced. On the other hand, home area networks, commercial building energy management system enabling technologies, and other new technologies have or soon will be commercialized and will undoubtedly contribute to smart grid savings in the future.

Smart grid program evaluations reflect a forecasting and analysis challenge that utilities and their regulators have just begun to consider. Previous smart grid analysis results and studies are of little use in utility-specific applications; nearly all customer smart grid impact studies rely on simple elasticity models that are notoriously unreliable in situations where the underlying economic/technology structure is in a period of flux and where most of the benefits will occur in the medium and long term. In addition, studies typically focus on technical or achievable potentials providing little guidance concerning likely actual program achievements.

While elasticity-based estimates may be useful in defining a range of likely smart grid impacts, applying these ranges or the midpoint of these ranges in discounted present value calculations over fifteen or twenty years, as required in utility cost analysis, provides, at best, tenuous results. Utility regulators recognize these problems and in many cases reject utility smart grid funding requests because of the uncertainty associated with medium and longer-term load reduction estimates.

The MAISY agent-based end-use model described in the next section resolves these problems by recognizing variations across service areas and over time in individual customers, equipment, efficiency, dwelling unit, end-use hourly loads and other factors. The model is referred to as agent-based because it reflects electricity use of individual utility customers or ‘agents.’

MAISY AGENT-BASED END-USE MODELS

The application of traditional end-use models to evaluate smart grid programs is limited because these models use customer segments that do not translate directly to smart grid program participants. That is, only a portion of single-family households with central air conditioning will participate in smart grid programs and participants are likely to reflect different energy use characteristics compared to non-participants. Since traditional end-use models calculate electricity use by applying averages for customer segments (i.e., an average for single family households with central air conditioning) the models cannot explicitly reflect smart grid impacts. In addition, most traditional end-use models do not include end-use hourly load data required to explicitly evaluate end-use load impacts.

The solution to explicitly modeling utility smart grid program impacts is to apply an agent-based end-use modeling approach. Agent-based models apply the same efficiency, fuel utilization, equipment replacement and other modeling relationships as end-use models; however, the agent-based end-use modeling process is applied to each individual agent or customer in a statistically representative sample rather than to an aggregate customer segment. Agent-based models are widely used in modeling applications outside the utility industry.

An agent-based modeling approach provides direct access to all customer detail required to assess smart grid program impacts. Program responses are determined by impacts on end-use hourly loads of individual program participants.

Agent-based electricity end-use modeling methodology is intuitive. The utility service area is represented by a statistically representative sample of utility customers. End-use equipment holdings, end-use electricity use and hourly loads along with income, demographic and other variables characterize each customer. Each customer record is updated in each year of the forecast to reflect changes in end-use equipment efficiency and the impacts of changes in income, demographics, electricity prices and other factors. Customers are added to the sample to reflect growth in the service area over time.

The MAISY (Market Analysis and Information System) residential agent-based model applied in this study reflects an extension of the REDMS (Residential Energy Use Modeling System) model first introduced in 1981 and extended over the years to meet changing electric utility industry needs. While REDMS model versions applied agent-based modeling to forecast fuel and efficiency choices beginning in the late 1980s, the current version has extended agent-based modeling to the entire modeling process.

A smart grid program is modeled at the individual customer level by smoothing individual central air conditioner and water heating hourly loads over peak hours to reflect utility and customer-sited control technologies and by additional reductions in end-use electricity use based on price responsiveness revealed in pilot pricing programs and supported by end-use load shifting and additional changes in thermostat settings. This smart grid analysis provides a more reliable analysis than aggregate elasticity modeling approaches because estimated hourly load reductions are based on actual end-use equipment information, including end-use hourly loads, associated with individual households in the service area.

DUKE ENERGY INDIANA CASE STUDY

The Duke Energy Indiana service area was selected as a case study application; however, Duke was not involved in this research and any conclusions drawn from the study do not necessarily reflect Duke Energy views.

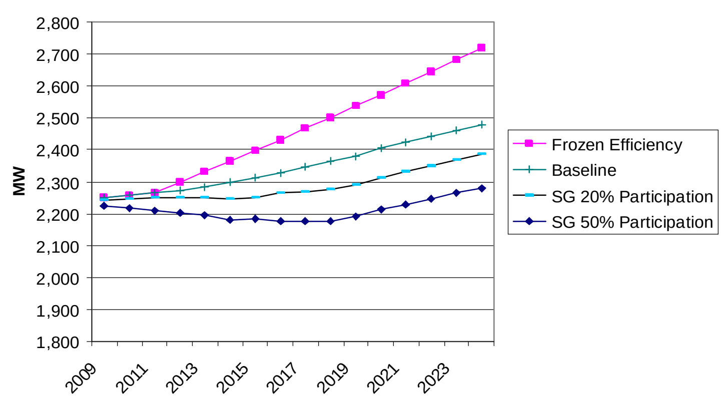
Duke Energy Indiana provides electricity to nearly 700,000 customers in 69 counties in the central, north central, and southern parts of the state. Duke Indiana customers will experience a 20 percent rate increase over the next five years to pay for a new coal gasification plant now under construction. Duke Indiana is planning a smart grid implementation throughout the service area.

MAISY Utility Customer Energy Use and Hourly Loads Databases provided information on a representative sample of 1,350 Duke Indiana residential customers including their electricity use, hourly loads, income, demographics and so on.

Two program participation rates were applied in the forecast. A 20 percent participation was included as a reasonable lower bound with a 50 percent participation reflecting something close to a maximum achievable voluntary pricing program participation. A residential customer growth rate of 1.2 percent was used in the forecast period, consistent with the 1998 – 2008 growth rate.

Figure 1 shows four Duke Energy Indiana forecasts provided by the MAISY agent-based end-use model. The frozen efficiency forecast provides an estimate of August residential peak loads in MegaWatts (MW) over the next fifteen years assuming equipment efficiencies and utilization remain constant. That is, in the absence of the impacts of appliance standards, building standards, electricity price increases and so on. Under this scenario the peak residential load increases at an annual rate of 1.3 percent. This forecast scenario is included as reminders that a variety of structural changes are underway that act to reduce future electricity use and peak hour loads.

Figure 1. Residential Smart Grid August Peak Loads



The baseline forecast shows peak load increases of 0.6 percent. The reduction compared to the frozen efficiency case is a result of the 20 percent electricity price increase that occurs through 2011 and the impact of appliance and building efficiency standards as well as voluntary efficiency improvements.

The smart grid 20% participation scenario shows the impacts of a smart grid program that impacts central air conditioning and water heating and includes peak hour pricing incentives. It is assumed that participation grows to 20 percent in the first ten years of the forecast and is maintained at 20 percent through the remaining five years. The smart grid program reduces peak annual growth to 0.4 percent and provides a total residential peak demand reduction of 98 MW at the end of fifteen years.

The smart grid 50% participation scenario shows that a comprehensive smart grid program achieving 50 percent participation by the tenth forecast year could reduce peak annual growth to 0.2 percent and reduce peak demand by 198 MW.

The two smart grid peak demand savings of 93 and 198 MW reflect reductions of 4 and 8 percent in residential peak load contributions. Industry average avoided costs and AMI-associated savings suggest that a Duke Energy Indiana smart grid program would provide a significant net present value.

The detailed monthly MAISY peak period hourly load forecasts can be used in detailed discounted net present value analysis.

The utility customer-detailed nature of the model, permits easy evaluations and insight on smart grid program design. For example, Figure 2 shows a majority of air conditioning potential in income segments with annual incomes greater than $50,000 while in Figure 3 a majority of water heating potential exist in households with annual incomes less than $50,000

Figure 2. Air Conditioning Smart Grid Potential by Income Segment

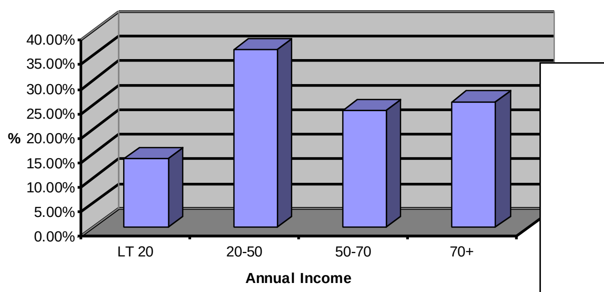
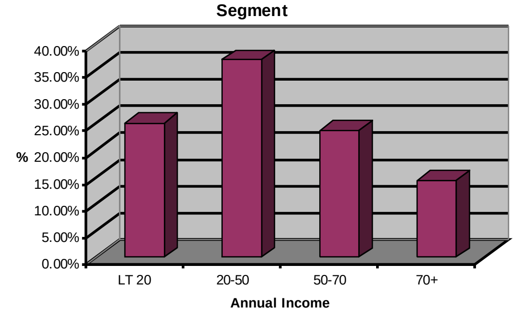


Figure 3. Water Heating Smart Grid Potential By Income Segment



CONCLUSION

This study shows that smart grid hourly load impact models based on aggregate elasticities provide unreliable results when applied across utilities and over time because these models ignore geographic and time variations in factors that determine utility customer smart grid program responses. These differences in electricity prices, income, demographics, appliance saturations, efficiencies, and other factors are explicitly addressed in the MAISY agent-based end-use model and applied to analyze peak hour electricity savings for a Duke Energy Indiana smart grid implementation. MAISY Utility Customer Databases are the source of the utility customer hourly load and other information applied in the independent study.   Duke Energy did not fund or participate in the study.

Agent-based models provide a more accurate and insightful analysis of smart grid impacts because they reflect electricity use of individual utility customers or agents. The models are intuitive and simultaneously recognize and account for all important factors that determine electricity use of individual customers including income, demographics and other factors. Agent-based models are widely used in modeling applications outside the utility industry.

Study results show that Duke Indiana smart grid programs can expect to achieve between 4 and 8 percent reductions in residential summer peak loads over a 15-year period, achieving what is likely to be significant net present value associated with the implementation.

The customer information applied in the MAISY models can provide a detailed picture of smart grid potentials and customer characteristics for any desired customer segment. This information supports detailed program development and analysis and permits the development of marketing strategies to increase program participation and customer value. The agent-based platform is also consistent with data developed from pilot programs, AMI deployment and smart grid program applications. Customer information can be used to refine the models while model applications can be used to score customers and develop targeted programs.

Finally, MAISY agent-based end-use models provide traditional electricity demand forecasts including energy and hourly load forecasts as well as energy-efficiency and other utility program analysis.