THE UTILITY SMART GRID BUSINESS CASE: PROBLEMS, PITFALLS AND TEN *REAL-WORLD* RECOMMENDATIONS

Studies published over the past several years report impressive returns on smart grid investments. However, these studies reflect cost/benefit evaluations and models that, for many reasons, cannot be applied directly to evaluate individual utility investments. The lack of a standard, commonly accepted utility-level cost/benefit framework has led to a number of utility smart grid investment analysis approaches that poorly serve utility decision-makers.

This paper describes the challenge utilities face in developing comprehensive investment strategies and identifies difficulties associated with several common approaches to smart grid investment analysis. The final section presents ten investment analysis recommendations based on the Smart Grid Research Consortium's cost/benefit model that has been applied at 15 utilities. These recommendations are offered both to guide utility in-house analysis and to assist utilities in evaluating smart grid analysis undertaken by vendors and consultants.

Jerry Jackson, Ph.D.,
Leader and Research Director
Smart Grid Research Consortium
jjackson@smartgridresearchconsortium.org
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37 N. Orange Avenue, Suite 500
Orlando, Fl 32801
www.smartgridresearchconsortium.org
407-926-4048

PROBLEMS APPLYING EXISTING STUDIES

Studies published by FERC, DOE, EPRI and other organizations over the last several years report impressive benefit/cost ratios for smart grid investments[1]. The earliest of these studies focused primarily on potential savings and costs of AMI/smart meters coupled with behind-the-meter technologies (e.g., programmable communicating thermostats) and utility programs (e.g., critical peak pricing). The most recent EPRI analysis includes transmission and distribution technologies, estimating total United States benefits to be 2.8 to 6.0 times greater than costs.

While these studies provide useful information from a general public policy perspective, their broad geographic scope and the use of average or "typical" characterizations for technology and program costs, benefits, hourly load impacts and other inputs provides little value in assessing actual detailed smart grid investment options at individual utilities. Variation among utilities in existing infrastructure (e.g., current communications and metering systems), service area characteristics (e.g., customer geographic density) and customer end-use loads (e.g., residential central air conditioning) even within a single state is so great no utility decision maker would rely on these studies to justify smart grid investments.

Several state-level efforts have been undertaken to provide guidance in evaluating the smart grid business case.[2] While these activities provide useful background material, their results fall well short of detailed "how-to" prescriptions that would be most useful for individual utility applications. Some utility regulatory filings provide a useful general starting point for utility financial investment analysis; however, much of the analysis detail is omitted in publicly available material while the few utility filings that are available are for utilities whose size, climate and other factors make their applications quite unique.

The Department of Energy has developed a smart grid financial analysis spreadsheet model to evaluate costs and benefits of APPA-funded smart grid projects after investments have been made.[3] However, the model's *ex post* perspective provides little value in developing optimal investment strategies prior to undertaking smart grid implementations. For example, rather than determining impacts of technologies and program parameters on system hourly loads as part of the analysis, this model requires users to specify those end results as part of the analysis input.

In conclusion, no publicly available, commonly accepted, comprehensive financial model has been available to assist utilities in applying enterprise-wide smart grid cost-benefit analysis.

TWO COMMON PITFALLS

The lack of a standard quantitative framework appropriate for utility smart grid analysis has given rise to several financial analysis approaches that result in suboptimal investment strategies. Two of the most common of these limiting approaches are briefly described below.

Limited-Option Analysis. Smart grid investment decisions are often viewed as a sequential decision process where individual investment options are considered in isolation from related options and applications. For example, AMI/Smart meter investments are often evaluated ignoring the role that AMI communications and smart meters can play in demand response programs and substation and feeder automation. In addition to ignoring technology and customer program interactions and synergies, a sequential single- or limited-option implementation strategy overlooks implementation coordination and timing options that can significantly increase investment returns. In-premise technologies and demand response program impacts may be secondary to AMI benefits at many utilities; however, delaying the development of these applications until after the full AMI and meter data management system implementation has been completed can significantly reduce returns on AMI system. A limited-option analysis approach may be undertaken by utility staff constrained by time or resources or it may be undertaken on behalf of the utility by vendors who are focusing on their individual technologies; however, limiting the scope of smart grid analysis to a subset of smart grid technologies and programs is almost certain to result in lower returns on the utility's entire smart grid investment portfolio.

Limited Hourly Load Impact Analysis. Most utilities do not have information on customer class, end-use (e.g., residential AC, residential water heat, commercial lighting, etc.) hourly loads and hourly load forecasts required to evaluate benefit contributions associated with direct load control, pricing programs, customer engagement and in-premise technologies and programs such as programmable communicating thermostats and critical peak pricing programs. Rather than developing this information to design and quantify effective customer program strategies, most analysis applies a rule-of-thumb assumption with system peak demand to estimate avoided power costs and avoided distribution capacity investments. This approach ignores management of all hourly loads in critical peak periods and times when distribution systems stress can be reduced with a variety of demand management initiatives. Since benefits associated with reduced hourly loads can vary from 20 to 60 percent of total smart grid investment benefits, depending on utility customer characteristics, weather, etc., the application of an average rule-of-thumb assumption is wholly inadequate.

Detailed customer hourly loads analysis and forecasting is a well-developed area that has been applied for more than three decades to evaluate costs and benefits of energy efficiency and other utility programs and should be included in all smart grid investment analysis. This omission is often associated with analysis provided by engineering consultants and technology vendors who may have little experience or knowledge concerning customer-related technology and/or program impacts.

Limiting smart grid investment analysis by excluding technologies, programs, customer hourly loads and other variables that are important determinants of smart grid costs and benefits can be expected to result in a smart grid system with greater cost and smaller benefits than would be the case if a comprehensive, integrated, quantitative financial analysis framework were applied.

THE SMART GRID INVESTMENT ANALYSIS CHALLENGE

Electric utilities are experienced at making capital investment decisions. Many of the issues associated with smart grid investments are present in traditional generation, transmission and distribution investment analysis. However, surveys of utility decision-makers consistently identify "making the business case" as one of the greatest challenges in developing smart grid investment strategies. The Smart Grid Research Consortium's national survey of electric cooperatives and public utilities conducted in July 2010 found that nearly 90 percent do not apply formal investment models to evaluate smart grid options.[4]

Why are utilities having such difficulty evaluating smart grid investment options? The Smart Grid Research Consortium's investment analysis experience at fifteen utilities identifies both the reasons for the difficulty in developing acceptable utility-specific investment analysis and requirements to overcome these difficulties.

Smart grid investment analysis is especially difficult because of (1) the large number of technologies, software, programs and operational practices that (2) cut across nearly all operational areas within the electric utility organization (3) in ways that often impact each other, (4) require a decade or more to fully implement and (5) depend on hourly load contributions of customer in-premise technologies and programs.

Given the problem statement above, a solution is easy enough to identify, at least in general terms.

> *Smart grid investment analysis requires a financial model that considers costs and benefits of all potential smart grid technologies, software, programs and operational practices over a sufficiently long planning horizon in a way that reflects interactions among the components and recognizes the importance of customer hourly load contributions. That is, smart grid investment analysis requires comprehensive long-run enterprise-wide detailed cost/benefit analysis.*

While other investment analysis challenges such as uncertainty, interoperability, technology obsolescence and other factors are important these issues can be addressed with conventional analysis techniques and are secondary in importance to applying a comprehensive, consistent, long-run, enterprise-wide cost/benefit framework specifically developed to evaluate smart grid investments.

TEN REAL-WORLD RECOMMENDATIONS

It is relatively easy to conceptually specify a smart grid cost/benefit model that meets the requirements in the previous section. The reports referenced earlier provide well-recognized lists of potential smart grid technologies and programs. An Excel spreadsheet can be developed to include cost and benefit parameters for each technology/program each month or quarter in the year to show expected costs and benefits by equipment and program categories. Linkages between technologies and programs are specified to reflect the interactions and synergies discussed earlier. A traditional customer class end-use detailed hourly load model component can be included to determine technology and program impacts on hourly loads over the planning horizon. Avoided power purchase, generation, transmission and distribution costs and avoided capacity investment costs can be determined as a function of reductions in hourly loads. Users can specify inputs to reflect combinations of technologies, programs and timing. High and low values can be used in the analysis to consider uncertainty.

The Smart Grid Research Consortium, which was formed in 2010, developed and implemented a smart grid investment cost/benefit model for electric cooperatives and public utilities applying this conceptual approach. The Consortium's investment modeling project started from scratch: reviewing smart grid technologies, software, programs, and past cost/benefit analysis, discussing issues with vendors and developing the framework and intuitive user interface. The Consortium's objective was to provide a long-run enterprise-wide cost/benefit investment model that met (1) the modeling objectives stated in the previous section and (2) smart grid financial analysis and planning requirements of all individual Consortium members including small and large electric cooperatives and municipal utilities.

The Consortium's Smart Grid Investment Model™ (SGIM) was reviewed by Consortium members and revised in response to member suggestions. The model has been applied for fifteen Consortium member utitlies including 8 cooperatives, 5 municipal utilities, 1 public power district and 1 generation and transmission utility.

The SGIM includes technologies and programs that range from distribution substations to applications inside customer premises. The model is built on an Excel platform with a callable hourly load forecasting/smart grid impact model that determines technology and program kW impacts along with associated financial benefits. The model is organized with individual worksheets devoted to costs and benefits for AMI/smart meters, distribution automation, and customer-oriented technologies and programs with a summary results worksheet that provides investment analysis by quarter and year. (Additional detail on the model is provided at http://smartgridresearchconsortium.org/notes.htm)

In addition to providing individual utility smart grid investment models, Consortium efforts demonstrated that a basic smart grid investment cost/benefit framework can be applied to all utilities with individual utility characteristics represented in separate implementation activities.

The Consortium's experience developing and applying the Smart Grid Investment Model suggests that the following ten recommendations should be seriously considered in every utility-level smart grid investment analysis. These recommendations are offered both to guide utility in-house analysis and to assist utilities in evaluating smart grid analysis undertaken by vendors and consultants.

1. Modeling Framework. The complex technology, program and customer relationships included in smart grid investment analysis along with the long-term (e.g., 15 years) nature of financial analysis require a formal modeling approach. Only a formal model provides the scenario analysis and interactive capabilities required in developing investment analysis strategies when such a large number of variables and interactions exist. Utilities who engage consultants or vendors to evaluate and identify smart grid investment strategies should require a formal model as a project deliverable. Note that a "spreadsheet tool" that requires users to input most cost and benefit values is not a model. An investment model requires the integration of costs, benefits, customer load forecasts, technology and program interactions such that only program and strategy values (technologies/programs, implementation dates, etc) and financial parameters (discount rate, analysis period) are modified by users in assessing smart grid investment options.

2. Long-Term Planning Resource. A smart grid investment model should be viewed as a required financial planning tool to be maintained and applied until the smart grid investment transformation has been completed. It may only take several years to upgrade a communications system and implement an AMI/smart meter system; however, the build-out of a meter data management and other software management systems, development and implementation of a distribution automation system and establishment and refinement of behind-the-meter programs and technologies is likely to cover more than a decade. A useful investment model should (1) support strategy development and define targets prior to investing, (2) evaluate technology and program implementation, (3) support strategy revisions as important factors change and (4) provide continuous benchmarking evaluations.

3. In-house Analysis Capability. At least one individual in the utility should be familiar with the model, and have the ability to conduct in-house analysis. This individual should serve as the "smart grid investment guru" and communicate data needs and results to the various departments and management of the utility.

4. Scope. Smart grid technologies, software and programs are so interdependent within the distribution system that the financial model should include and integrate costs and benefits of all important smart grid components from the substation to behind-the-meter technologies and programs. The model should also include, as appropriate, avoided purchased power and transmission charges, avoided GT&D capital costs as well as management reengineering and other costs. Related products and services (e.g., water and natural gas applications, other communications-related services) should be included.

5. Scalability. The financial model should be scaleable; that is, it should be possible to extend the model to address new or more detailed applications without having to change the basic model structure or modeling process.

6. Utility Detail. The model should include all utility and utility customer detail (e.g., customer class kWh, electric space heating appliance saturations) relevant to evaluating utility-specific smart grid investments.

Relevant utility infrastructure characteristics (e.g., current communications systems characteristics) should be included to provide a baseline for the investment analysis.

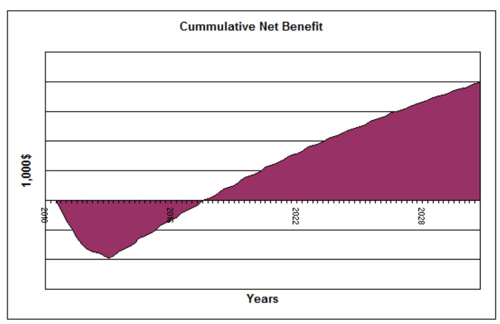
7. Utility Hourly Load Forecasts. Hourly load impacts of direct load control, pricing programs, customer engagement and in-premise technologies and programs such as programmable communicating thermostats and critical peak pricing programs are important contributors to smart grid benefits. Determining these impacts for each utility requires (1) information on current customer class, end-use (e.g., residential AC, residential water heat, commercial lighting, etc.) hourly loads and (2) hourly load forecasting models to reflect growth in detailed hourly loads as a result of customer growth, changes in electric equipment saturations, and other factors in addition to smart grid technologies and programs.

8. Alternatives Strategies. Preferred investment strategies will differ by utility depending on utility and customer characteristics and utility management objectives. Some utilities will focus early investment on distribution automation, others will begin by implementing AMI systems while other utilities will launch efforts in many areas at once. A robust financial investment model must have the capability to quantify the financial implications of alternative strategies and to provide insights on the timing and integration of smart grid initiatives across the enterprises. Scenario analysis provides investment analysis results under alternative assumptions on model parameters and can be applied to evaluate the impact of uncertainty on investment outcomes.

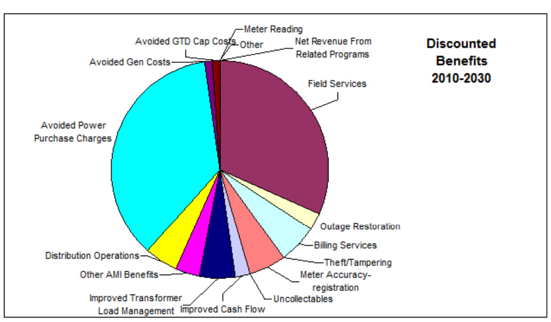
9. Intuitive Results. Many participants in the utility decision-making process do not possess technical backgrounds; consequently, financial and engineering results should be presented both in summary intuitive formats and detailed technical presentations to support informed decisions by all stakeholders.

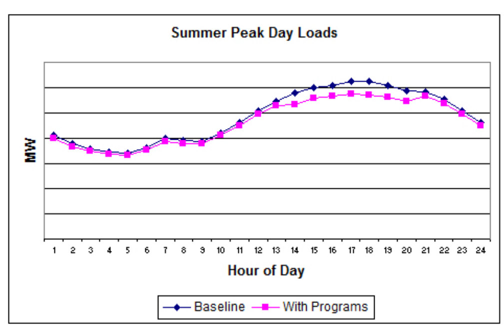
For example, the Consortium model utilizes an Excel Workbook as the basic software platform to provide a familiar, transparent view of all calculations. Mathematical formulations in the hourly load forecasting models are applied in a software module executed by the workbook. Traditional financial calculations (e.g., net present value) should, of course, be included; however, simple and discounted payback should also be provided.

Intuitive graphical presentations should be included. For example, the Consortium model's break-even curves (see chart on right) present quarterly net benefit (cumulative benefit minus cumulative costs) to show how much total project benefits exceed total project costs at any point in time.



Traditional pie charts provide insights on detailed sources of total costs and benefits while before- and-after peak day loads profiles reflect program impacts (below). The Excel framework also provides users the ability to add their own tables and charts with familiar Excel operations.





10. Strategic Refinement. Many in-house utility financial investment analyses derail as the challenge of developing dozens of relationships and hundreds of parameters becomes apparent. However, investing resources to determine a relationship or parameter that represents a relatively unimportant cost or benefit for a particular utility is a poor use of resources. Consequently, sensitivity analysis should be conducted to identify parameters and relationships that have the greatest impact on investment returns with those parameters and relationships given the greatest refinement priority. Sensitivity analysis is conducted by evaluating change in investment results when parameters are varied within reasonable bounds. This parameter evaluation and refinement is best accomplished in collaboration with knowledgeable staff in individual departments (i.e., billing, metering, distribution engineering, etc.) and with vendor information.

ABOUT THE SMART GRID RESEARCH CONSORTIUM

The Smart Grid Research Consortium is an independent research Consortium open to electric cooperatives, municipal and other public utilities. Consortium members contribute input on project direction and receive benefits of a large-scale research project while sharing costs with other Consortium members. Each Consortium member utility receives a Smart Grid Investment Model customized for their utility including monthly customer class/end-use kWh, peak kW and load profile forecasting models and smart grid impact analysis, a User and Resource Guide and two complementary passes to the October 20-21 2011 conference in Orlando. The Model supports smart grid investment analysis at every stage of the smart grid process from initial planning to benchmarking and verification of technology and program impacts after implementation. Additional details including membership information is available on the Consortium Web site: http://smartgridresearchconsortium.org/

ABOUT THE AUTHOR

Dr. Jerry Jackson, leader and research director of the Smart Grid Research Consortium, is an energy economist with more than thirty years experience in utility forecasting, utility program development and analysis, and new energy technology market analysis. He was previously a professor at Texas A&M University and Chief of the Applied Research Division at Georgia Tech Research Institute. He is also president of a Jackson Associates where he has worked with utilities, state regulatory agencies, equipment manufacturers and others in addressing energy industry issues. His clients include more than fifty utilities ranging from small coops and municipal utilities to the largest investor owned utilities in the US and Canada. He has assisted leading technology companies including United Technologies, Ingersoll Rand, Toyota, Sungevity, Ice Energy and others in analyzing and evaluating markets for new energy-related technologies including fuel cells, microturbines, combined heat and power, solar technologies, cool storage, flywheel and demand response programs. Email: jjackson@smartgridresearchconsortium.org

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[1] Representative study reports include: (a) Baer, Walter S., Fulton, Brent . Mahnovski, Sergej, "Estimating the Benefits of the GridWise Initiative," Phase I Report, Rand Science and Technology Technical Report, Prepared for the Pacific Northwest National Laboratory, May, 2004, (b) Federal Energy Regulatory Commission, "A National Assessment of Demand Response Potential," June, 2009, (c) "Estimating the Costs and Benefits of the Smart Grid: A Preliminary Estimate of the Investment Requirements and the Resultant Benefits of a Fully Functioning Smart Grid, Electric Power Research Institute, March 2011,(d) The Costs and Benefits of Smart Meters for Residential Customers, Institute for Electric Efficiency, July 2011.

[2] Study reports include: (a) Smart Grid Maryland: Smart Grid Technologies and Programs, Maryland Energy Administration May, 2009, West Virginia Smart Grid Implementation Plan Revision 1, West Virginia Division of Energy August 20, 2009, (c) Collaborative Report, Illinois Statewide Smart Grid Collaborative September 30, 2010.

[3] User Guide For The U.S. Department Of Energy Smart Grid Computational Tool (SGCT) Guide for SGCT Public Version 1.1, Department of Energy Oak Ridge National Laboratory, December, 2010

[4] Jackson, Jerry, "Evaluating Smart Grid Investments at US Cooperative and Municipal Utilities" Metering International, Volume 1, 2011, available at http://smartgridresearchconsortium.org/Metering_International.pdf .