Using the Smart Grid Intelligently

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ABSTRACT

Utilities are investing millions of dollars in ratepayer and / or federal funds to develop the smart grid. But in many cases, they are failing to integrate these efforts with existing or planned investment in energy efficiency, demand response, and distributed energy resources.

This failure comes at a time when unprecedented levels of energy efficiency resource acquisition are taking place, when "deep" levels of savings are becoming more common in new and existing buildings, and when distributed energy resources are emerging as a viable resource for meeting customer energy needs.

The smart grid could be a natural partner and facilitator of these emerging energy resource strategies. Will utilities and regulators recognize the potential of the smart grid to facilitate a new, more decentralized approach to providing energy services? Will they recognize the smart grid as vital tool for customer involvement and empowerment? Will a new approach that makes customers part of the utility resource mix be reflected in utility resource planning and cost recovery?

Given this potential for significant impacts in energy resource strategy, a unique opportunity has emerged in Vermont, one that offers the possibility of truly innovative development and use of the smart grid. Vermont law requires that priority be given to energy efficiency and least-cost integrated planning. It is now actively investigating how this principle applies to smart grid implementation.

The Potential of the Smart Grid

The smart grid has the potential to decentralize the operation of an historically centralized industry, and to empower customers in the process. The smart grid could enable dramatic changes in the efficiency of energy generation and use, and play a vital role in addressing the issues of climate change and energy security. It has the potential to fundamentally challenge and change the way electric utilities define their mission and relate to their customers.

The smart grid will deliver fully on this promise only with an unprecedented level of cooperation, understanding, and foresight from the major players creating the smart grid. In particular, national leaders, federal and state legislators, regulators, utilities, and various advocacy groups will significantly influence both the form that the smart grid evolution takes and the speed at which it proceeds.

Much of the power and transforming effect of the smart grid will be determined by decisions about how it is designed, developed, deployed by utilities, and the extent to which it empowers ratepayers to take control of their own energy consumption. Utility customers are still on the "receiving" side of the electric grid, which is a "central station" industry. In much the same way, customers have historically been on the receiving end of other public service infrastructure such as telecommunications.

If Alexander Graham Bell stepped back on earth momentarily and was handed an iPhone, he would have difficulty recognizing his invention—as the U.S. Department of Energy recently observed. On the other hand, if Thomas Edison and Nikola Tesla were to tour the existing electric grid, they would not only recognize their creation a century later, but, other than being impressed by its size and complexity, they might not know they were in an era that has largely converted from analog to digital technologies.[1]

The size, magnitude, and complexity of the electric grid are truly impressive. It has penetrated nearly every aspect of our daily living. The scale of potential change in the operation of the grid, the behavior of its users, and the makeup of its supply mix through the innovations that are together termed the *smart grid* are all comparable to the changes that have taken place over the last 30 years in telecommunications. But there is another reason that the scale and nature of this metamorphosis—and the potential for even more change in the grid—is so important.

A significant difference between the electric grid and the telecommunications industry is its impact on the environment. It is difficult to put the almost 4 trillion kilowatt-hours of energy that the U.S. electric grid delivered in 2007 into a context that allows one to appreciate the magnitude of that figure.[2] Perhaps it is even more instructive to look at what it took to make that much energy: 1 billion tons of coal, 110 million barrels of oil, and 6.7 trillion cubic feet of natural gas, along with energy from nuclear, hydroelectric, and other renewable sources.[3] This massive consumption of fossil fuels resulted in the electric grid being the largest emitter of carbon dioxide (CO_2) of any sector of the economy, comprising 40% of total U.S. CO_2 emissions with 2.5 trillion metric tons (gigatons) produced in 2007.[4]

While the electricity the grid delivers has environmental impacts that are significantly different from those from the telecommunications industry, there is strong potential for the smart grid to play a role in dramatically reducing these impacts. If the smart grid is aggressively designed to partner with and support the efforts to improve energy efficiency, to develop distributed (usually renewable) energy and combined heat and power (CHP) applications, and to improve the utilization of the grid, then the smart grid has the potential to help re-define the way energy infrastructure serves the public. It would do so by delivering energy from cleaner sources with greater efficiency and reliability, while simultaneously providing more equity and transparency for both electricity consumers and producers.

It is even possible that the smart grid, in combination with renewable energy development, the emergence of viable electric vehicles, improved storage technologies, and dramatically expanded capabilities in energy efficiency could lead to increased electrification as a major strategy to *combat* global climate change. Nevertheless, there is still a significant risk that the smart grid could simply be treated as an upgrade of the analog grid. The discussion of the smart grid in the context of utility planning has, to date, largely failed to explore the greatest potential it offers. One of the unfortunate dynamics unleashed by this restricted approach is that there is growing evidence that such a roll-out of the smart grid could generate strong customer and regulator opposition.[5]

[1] DOE, The Smart Grid -- An Introduction http://www.oe.energy.gov/DocumentsandMedia/DOE_SG_Book_Single_Pages(1).pdf
[2] EIA, 2007.
[3] 2007 EIA data
[4] Calculated from EIA data, 2007.
[5] In Texas, the publicity blitz against smart metering is spreading. A class action lawsuit has been filed against Oncor. The YouTube video at http://www.youtube.com/watch?v=tXcTjHt_9vU illustrates how the public views this.

This paper suggests how the smart grid, as a combination of smart devices *and intelligent uses,* could be vastly more. We offer this discussion of some initiatives in Vermont, to stimulate an exchange of ideas so that the value of the smart grid can be more fully realized in the future.

A Working Definition of the Smart Grid

The smart grid is defined by the Federal Energy Regulatory Commission as *"a power system architecture that permits two-way communication between the grid and essentially all devices that connect to it, ultimately all the way down to consumer appliances."*

These include:

- Synchrophasor devices to collect and store time-stamped snapshots of bulk grid voltage, frequency, and current flow—30 times per second;
- Distribution switches that can change feeds to customer circuits in the blink of an eye; and
- Customer meters that can continually provide energy use information to the customer and the utility, as well as provide dynamic price information to the customer and potentially provide price-responsive customer load management.

The uses to which these technical capabilities can be put are potentially transformative; for example:

- Bulk grid operators could use the synchrophasor data to monitor the rate of change for voltage, frequency, and current so that they know how the system is changing and whether trouble is approaching, rather than waiting for the system to reach a critical state;
- Distribution switches could move automatically to heal system failures and avoid outages based on the knowledge of existing short circuits and alternative flow paths;
- Reduced costs from interval meters and better information on loads and generation output to inform interconnection studies will facilitate distributed generation (DG);
- Utilities could employ usage data and voltage levels to dynamically reconfigure voltage settings, thus conserving energy consumption and meet minimum voltage standards;
- New electric storage systems, including batteries in electric vehicles, could be integrated into grid management, such as edge-of-grid voltage support.
- The data secured from buildings and discrete load areas can provide measured data that will document usage changes. This can improve verification of energy efficiency (EE) savings, improve renewable energy (RE) performance, suggest targeting of new applications, and improve the precision of load forecasting.
- It will be possible to use these data to identify customers for EE marketing
- Customers could use pricing and usage information, along with price signals from smart rate designs to improve their efficiency and to modify their use patterns, to reduce costs, and even program their appliances to manage themselves;
- Data from smart meters could be used to diagnose building energy use, analyze building performance, and detect operations inefficiencies; and
- Improved efficiency, distributed resource development, and demand response, combined with smart grid capabilities, could, in turn, affect the further evolution, design, and use of the grid.

This impressive array of technical possibilities is only the beginning of the potential that some thought leaders have suggested for the smart grid. We propose that this exciting list of capabilities, which is largely technical in nature, should be enhanced with a policy definition to guide smart grid implementation:

The smart grid should be developed to enable the greatest efficiency and reliability in the generation, delivery, and use of electricity while minimizing long-term consumer and environmental costs.

By defining the purpose of the smart grid through a clearly articulated policy, important guidance for smart grid implementation will be provided.

The Vermont Context

Vermont law provides a clear framework within which to consider the purpose and role of smart grid implementation: Section § 202a, Chapter 5 of Title 30, *Vermont Statutes Annotated* states:

> *It is the general policy of the state of Vermont:*
> *(1) To assure, to the greatest extent practicable, that Vermont can meet its energy service needs in a manner that is adequate, reliable, secure and sustainable; that assures affordability and encourages the state's economic vitality, the efficient use of energy resources and cost effective demand side management; and that is environmentally sound.*
>
> *(2) To identify and evaluate on an ongoing basis, resources that will meet Vermont's energy service needs in accordance with the principles of least cost integrated planning; including efficiency, conservation and load management alternatives, wise use of renewable resources and environmentally sound energy supply.*

Vermont's regulatory structure is a shared effort to provide service to retail electric customers. The Vermont Electric Power Company (VELCO) provides bulk power distribution to the Vermont sub-transmission companies and distribution utilities (DUs); the DUs wheel power to retail customers; and Vermont's Energy Efficiency Utility (EEU; Efficiency Vermont) delivers energy efficiency services.[6] These service providers together efficiently provide power to their customers and reliability to the grid. In addition, Vermont has a collaborative, statewide transmission and distribution planning process to consider the role of wires and non-wires [EE, demand response (DR), and distributed energy resources (DER)] solutions to meet the system requirements at the least cost. The Vermont load zone is the only vertically integrated utility business environment remaining in New England and the only long-standing regional statewide sub-pool. That is, the state is a single load zone in today's competitive marketplace, because of VELCO's statewide bulk power grid.

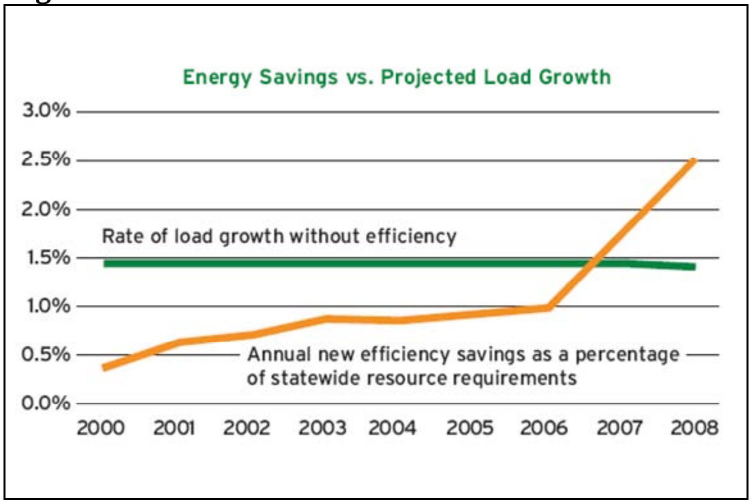
Vermont has a history of innovative and exemplary deployment of electric energy efficiency programs, and it has the country's highest per capita investment rates in efficiency. In the last decade, the EEU has significantly reduced the level of energy and capacity growth in

[6] Burlington Electric Department, a municipal distribution utility, delivers energy efficiency within the City of Burlington, its service territory. BED and Efficiency Vermont are collectively referred to as the EEUs.

Vermont with aggressive energy efficiency services for all customer classes and building types. In the past four years, more intensive EE effort has been targeted to geographically constrained areas. Annual savings levels have reached 3.8% of utility-identified load-constrained areas, and have attained impressive capacity savings, all at lifetime kWh savings of 3.8 cents per kWh (about 1 cent per kWh higher than the statewide efficiency savings average).

In fact, statewide efficiency savings in 2007, 2008, and 2009 have turned Vermont's load growth negative, as **Figure 1** illustrates:

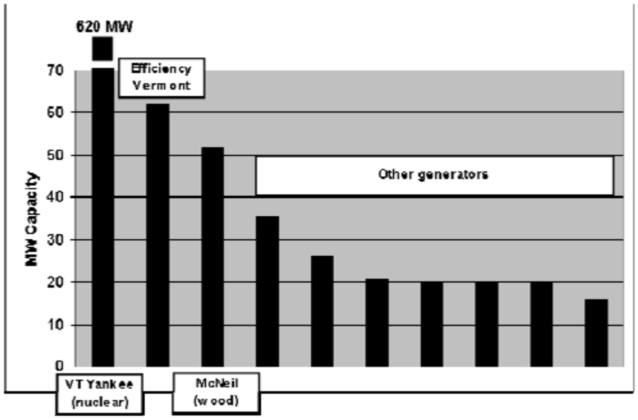
Figure 1. Percent of Annual Load Growth in Vermont



Source: Efficiency Vermont Annual Report 2008

Figure 2 indicates that the accumulated savings from energy efficiency investment mean that efficiency has become Vermont's second-largest power plant.

Figure 2. Energy Efficiency: Vermont's Second Largest Power Plant



Based on data from ISO New England (FCA3 Obligations)

Vermont has also been a leader in renewable energy initiatives. The state has a net metering program to support small, on-site distributed generation by customers. Vermont also recently offered a feed-in tariff rate to support small renewable projects of less than 2.2 MW at a rate intended to provide a return on equity comparable to a utility investment. The program is currently capped at 50 MW and is fully subscribed with a substantial amount of small solar, wind, and biomass distributed energy resources.

Finally, Vermont has set ambitious goals for deep levels of thermal efficiency; increasingly, the work of the EEU addresses whole-building and all-fuels efficiency, not just electric efficiency. Whereas many of the immediate smart grid benefits might be in electric end uses, the benefits of the smart grid to consumers must take into consideration the opportunities to produce whole-house energy savings that include gas, propane, and oil heat.

Vermont's Unique Opportunity

Vermont has an opportunity to implement basic components of the smart grid across all of its electric utility service territories. On October 28, 2009, Vermont was awarded a $69 million grant through the American Recovery and Reinvestment Act (ARRA). An additional $69 million cost-share requirement from utilities is required to implement a statewide initiative for a common fiber optic network backbone with independent smart meter roll-outs, including data collection and management systems to electric customers throughout the state. Most electric customers are expected to have smart meters in three years.[7]

Planning for implementation of the ARRA grant project is under way. The goal of the project is to achieve over 85% penetration of smart meters in Vermont households and businesses within two years.[8] Other aspects of the project include:

- Customer incentives for peak shaving;
- Customers empowered to change their energy consumption habits, via the display of their real-time electricity usage with evaluation of different types of consumer displays and the option of end-use monitoring;
- A test of enhanced over-the-phone counseling from the Energy Efficiency Utility, based on real-time, simultaneous viewing of smart-grid enabled energy data by both the customer and energy efficiency advisors;
- A test of the incremental impact of dynamic price display and / or notification;
- Statistically rigorous data from pricing, social networking, home automation trials, and grid automation results reporting;
- Secure interoperable control systems for substations and generation facilities; and
- Possible field testing Worldwide Interoperability for Microwave Access (WiMAX) technology as a precursor to a statewide standard.

The ARRA grant project presents a remarkable opportunity to implement a statewide smart grid approach that provides a leading model in three critical and interrelated areas:

1. There is an opportunity to construct open architecture for the Vermont smart grid, providing consistency and adaptability across multiple utility service territories and

[7] Burlington Free Press, October 28, 2009 State wins $69 million 'smart grid' grant. The full description of the grant project is: "Expand the deployment of Vermont smart meters from the current 28,000 to 300,000, implement customer systems such as in-home displays and digitally controlled appliances, secure control systems for substations and generation facilities, and automate the electric distribution and transmission system grids." http://www.spartnerships.com/reports/ARRA%20Smart%20Grid%20Investment%20Grant%20Awards.pdf.
[8] eEnergy Vermont, Smart grid Investment Grant application, DE-FOA-0000058, August 6, 2009.

laying a solid foundation for future capabilities statewide. Vermont's energy consumer advocate, the Department of Public Service (DPS), and the State's Chief Technology Officer are spearheading efforts to maximize collaborative benefits and interoperability. The key features will be:

- Criteria for "last-mile communication" and meter wireless signals;
- Data exchange and warehousing, sharing, and reporting mechanisms;
- End-use control capability, including electric vehicle charging; and
- Meter data management system (MDMS) structure and data availability for customer support.

2. There is a unique opportunity to build on the strong relationships that both the investor-owned utilities and the public entities have with their customers, and that the EEUs have gained through their ten years of innovative work with Vermont consumers. New elements of that relationship are made possible via the smart grid, including:
    - Improved efficiency through customer electricity usage feedback;
    - Increased customer understanding of electric use costs with dynamic pricing, resulting in expected effective increases in system use;
    - Diagnostic analysis of customer facilities, and tracking and feedback about actual customer usage; and
3. There is the unprecedented challenge of integrating the customer-side resources (EE, DR, and DER) with both supply and wires planning to support and give priority to these strategies, consistent with Vermont law and regulatory policy, and to inform forecasts about just how the system itself will grow and emerge. It will be possible to use system operating information to further reduce losses and increase reliability by using the following:
    - Smart meter technology for distributed generation;
    - Distributed generation and intermittent renewable (solar PV and wind) data with weather data for improved resource output forecasting;
    - Monitoring / control of electric loads, including electric vehicle charging to manage wires loads; and
    - Ongoing assessment and implementation to secure cost-effective customer side resources.

Smart Grid as Consumer Empowerment

It is clear that there are risks with smart meter installations and customer feedback strategies. For example, the rollout of smart meters in California, along with critical peak pricing, peak load increases, and rate increases led to customer suspicion that smart meters were biased toward high readings and / or designed to increase utility revenues at customer expense. A Boulder, Colorado, effort showed mixed results, depending on customer motivation and knowledge.[9] Other jurisdictions have reported considerable customer pushback with Smart Meter projects that allegedly resulted in higher bills.[10]

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[9] *Wall Street Journal*, February 22, 2010, What Utilities Have Learned From Smart Meter Tests…And why they aren't putting those lessons to use, Rebecca Smith. *USA Today*, February 17, 2010, Utilities' transition to smart grid has promise, but potholes, too, Julie Schmit.

[10] The higher bills may be attributed to rate increases, critical peak pricing with higher than expected summer loads due to weather and in some cases more accurate measurement of consumption.

In its ten years of operation, the Vermont EEU has learned that it is not simply selling efficiency, but helping customers identify ways to gain savings, improve operations, and invest strategically. Increasingly building strong, positive relationships with customers is critical to achieving deep efficiency savings.[11] The same lessons will apply in the implementation of the smart grid. Smart grid rollout and the opportunity for real-time pricing may be a utility economist's dream, but the actual introduction of all aspects of the smart grid, including real-time pricing, needs to be offered in a supportive manner, not announced and imposed.

The underlying goal of the Vermont ARRA-funded smart grid upgrade (eEnergy Vermont) is to identify the value proposition for customers in a way that effectively supports state energy policy and utility objectives, and builds on the learning gained by Efficiency Vermont.[12]

Although eEnergy Vermont is just getting started, its players are already discussing collaborative efforts to publicize the smart grid project and to reach out to customers. Participating partners agree that a clear, consistent message is of paramount importance for the success of the project.

eEnergy Vermont offers significant opportunities to reduce costs and provide higher levels of service. Some savings, such as reduced meter reading costs, can be reaped soon. Other efforts such as intelligent rate design will depend in part on collecting customer data across several years. In the meantime, the service providers will work together on some joint and independent pilots and other experiments to provide information for all service providers in Vermont. For example, one utility will test pricing levels and communication methods for a peak time rebate (PTR). Another utility with smart meters already in place will pilot home area networks (HANs) and in-home displays (IHDs), in conjunction with energy efficiency measures. The EEU is an active participant in designing these pilot projects.

Feedback Stimulates Efficiency

Smart meters can provide usage data to customers in many ways:

- To stimulate energy efficiency, instantaneous data can be fed wirelessly to customers' in-home displays, with real-time support or from central data collection with data processing for self-supporting information.
- Real-time support can help customers understand how much electricity a certain device is using. The customer could call the EEU to look for ways to reduce consumption and the Customer Service representative could look at dynamic usage data together with customer, helping them to understand the data and what the data tell them about energy use and energy savings opportunities.

[11] Scudder Parker, Michael Wickenden, Blair Hamilton, *What Does It Take to Turn Load Growth Negative? A View from the Leading Edge.* Paper presented at the ACEEE Summer Study Conference, 2008.

[12] The Vermont Smart grid upgrade (eEnergy Vermont) is part of efforts are being made to wring all possible benefits for common state-wide components while recognizing the requirements for some system specific components to mesh with existing infrastructure and business needs. For example, the largest utility has not implemented smart metering. The second largest has AMR meters and data systems in place; while the third largest utility is in the process of rolling out AMI meters. eEnergy Vermont is also working with Vermont utility regulators, primarily the customer advocate, to reach a common understanding of the way costs will be recovered in retail rates to minimize the risk of misunderstandings that could jeopardize full cost recovery.

- Central data collection with data processing would analyze customers' use patterns via software on an in-home device or through the service provider.
- eEnergy Vermont will seek to collaborate on the choice of Web presentment software (for utilities without software already in place) to reduce costs and provide a common statewide "look and feel" to the information.
- Many customers are expected to have web presentment as their primary tool, which offers the opportunity for energy use analyses and efficiency recommendations from the EEU to customers. It might also provide alternative rate choice comparisons from the utility, including flat rates, time-of-use rates, peak-time rebate rates, Critical Peak Pricing (CPP), or other dynamic rate options.

Demand Response—A Partnership with Customers

Vermont is committed to maximizing the potential of Demand Response benefits and the approach will be carefully designed, with several options currently under consideration. It could start by introducing DR as an option made available to customers who are ready to use it to lower their bills. Smart meters will facilitate DR in several ways if they are used intelligently with customer education and appropriate rate design.

Passive DR. Vermont Peak Time Rebates (PTR) or CPP rates can be facilitated with smart meters, particularly with residential and small commercial customers. Although ISO New England, the regional transmission organization, has an existing DR program and some ongoing pilots, the expense to install meters expressly for this purpose is prohibitive for small customers.

CPP and real-time pricing are often used as examples of rate design changes that can accompany smart meters. CPP can be a very powerful stick to modify customer behavior. Alternatively, PTR can be an effective carrot that rewards effective demand reduction behavior, without potential bill increases from misunderstandings or mistakes by the customer. The ARRA grant project will experiment with PTRs to gain an understanding of Vermont-specific responses to rebate price levels and communication methods. Real-time rates have been discussed for decades and Smart Meters offer a new way to communicate the necessary price information. Although more granular price information might seem like an obvious way to stimulate price response, there are other policy goals and considerations that should inform an intelligent use of real-time price information.

Residential customers may not have enough information, time, or appetite for risk to use real-time pricing notification. A resolution by the National Association of State Utility Consumer Advocates supports the concept that dynamic pricing should be a voluntary option for residential customers, not a mandatory or "opt-out" program.[13] Vermont policy has leaned toward stable rates for residential customers—rates provided by traditional long-term stable power contracts and, more recently, price hedging by the supplying utility. Business customers may be better

[13] The National Association of State Utility Consumer Advocates (NASUCA) Resolution 2009-01, Advanced Electric Metering and Advanced Electric Metering Infrastructure Principles of the NASUCA., Section 7: "That the implementation of advanced metering should not lead to mandatory or "opt-out" dynamic pricing of electricity usage for residential and small commercial customers. Residential customers and small commercial customers should continue to be provided electricity under existing rate designs unless they affirmatively choose to receive dynamic prices that use smaller time increments, such as time-of-use rates or hourly pricing. Similarly, a customer should not be required to cycle off an air conditioner or other appliance in exchange for a bill credit unless the customer affirmatively chooses to be part of such a program."

equipped with responsive loads and cost management skills to respond to varying price signals. At the same time, utilities need revenues that match costs so that marginal-cost pricing, as well as long-term price signals to guide customer investments, need to be considered in rate design. Many business customers indicate they can manage price volatility, but they want long-term price predictability.

Active DR. Direct utility or vendor control of customer end uses is increasingly becoming an option. Engineers may be tempted to implement new technology devices and procedures as part of the smart grid, just because they can. Appliances might soon have a mind of their own. For example, appliance manufacturers are working with companies that build wireless control devices to enable DR in standard appliances such as water heaters, clothes dryers, and ovens, to shed load on signals from the utility on demand levels or price levels. Rather than the consumer figuring out how to manage refrigerator load, a smart refrigerator might execute an algorithm for power consumption, based on the owner's use patterns and power supply price signals.

Thus, the meter can allow communications to the customer, or even directly to an end-using device if the customer allows such an option. Manufacturers such as General Electric and Whirlpool are designing new appliances with peak load reduction capability and communication interfaces. So a residential customer could allow a utility partial control of the clothes dryer or oven or water heater, to reduce peak loads on the system. Such measures constitute conservation or DR, rather than efficiency, but the frequency is expected to be low with significant system costs savings to defer capacity upgrades for generation and wires. Existing off-peak electric water and space heat with storage could be switched to smart meter signals for reliable and automatic control, if the customer would like to be relieved of manual controls.

Smart Grid and Distributed Energy Resources

Interconnection costs, including metering costs, have been a market barrier for small distributed generation. Distributed energy resources will be facilitated to the extent that smart metering can improve communications and reduce measurement and reporting costs. To the extent that information about better system utilization and information about better DG output can inform interconnection studies, DER could move toward the desired end state of "plug and play," rather than burdensome analyses and expensive interconnection system changes. Dynamic system protection and control devices may be spawned from smart grid technology and thinking. Such improvement requires good design and careful development, and does not appear simply with the installation of Smart Meters and Meter Display Management Systems. For example, substantial data will need to be analyzed and methods will need to evolve to use the knowledge from that analysis to enhance load and output forecasts. Better information and methods for forecasting loads and the forecasting the output of intermittent resources such as solar and wind might facilitate DER by giving system dispatchers better tools for planning and for implementing short-term changes such as dispatching DR to support a downturn in solar or wind.

Customer Empowerment

Vermont customers will see some small, temporary rate increases from the smart grid investment. To varying degrees, the investment will be offset by the ARRA grant, reduced meter reading costs, and other systems benefit efficiency gains. Acceptance of the net cost increases by customers will depend in part on their ability to reap benefits from the smart grid. Investments in associated smart grid devices and software will also depend on customer expectations for net savings. Although early adopters of these technologies might not be as price-sensitive as the typical customer, there are not likely to be a sufficient number of them to exert a large effect on the grid.

The partnership between the Energy Efficiency Utility and the distribution utility provides the potential for a whole different set of benefits to customers and the system. While it will not be immediately obvious just how to quantify all of these benefits, the eEnergy Vermont partnership with the EEU means that smart grid implementation is focused on customers, their needs, their potential for savings and bill reductions, and increasing the viability of distributed resources in the Vermont resource mix. Since the EEU is increasingly providing "whole building" efficiency services, it is not unreasonable to expect that the smart grid capabilities might eventually be expanded to assist in the management of other non-electric energy uses in the home.

Some early bill savings can be expected from good communications about opportunities to participate in behavioral modifications such as shifting uses to off-peak for customers who have time-of-use rates or reducing unnecessary, phantom plug loads and lighting in unoccupied rooms. Some increased investments in efficient lighting or small appliances, as part of existing energy efficiency programs, can also be expected. Significant investments in efficient appliances or load-shifting appliances will require customer education—perhaps including training in life-cycle cost analysis, to justify the higher first costs for new appliances or appliance controllers to harvest savings from time-of-use rates. The EEU will work to integrate its services and incentive offers with the new information provided by the smart grid.

Some existing time-of-use rates with higher on-peak costs could also help stimulate solar PV or solar thermal investments where, in the first case, net metering rates are favorable during the day, and in the second case, offsetting electric water heating during the day could be cost-effective. Some customers might be attracted to more efficient electric devices to reduce their carbon footprint and costs. Devices such as electric cars could be more attractive to customers if the smart meter can be used to optimize charging cycles. On the utility side, attractive rate designs might be enabled by active load management of charging cycles, to avoid creation of a new peak during the previous off-peak time period. This can be accomplished by staggering loads across the system or on a single distribution circuit to avoid local distribution loads.

Smart metering could facilitate better generation metering data and monitoring of output to facilitate integration into the utility grid. Intelligent use of the data to produce better forecasts of intermittent renewable generation such as solar and wind could help system dispatchers.

Incorporating Lessons Learned into Transmission, Distribution, and Supply Planning

Although price signals might be adequate to manage system loads in the early years of electric vehicle use, for example, large penetrations of these devices might require active load management via smart meters and smart cars. Customer acceptance of new energy efficiency measures can inform the marketing of new devices and the design of customer incentives—and inform the extent to which customers are willing to share benefits with others. Intelligent use of rate designs and education to empower customers to make good decisions is a lesson to be learned from Vermont's energy efficiency program delivery experience.

Educating customers to consider fuel switch measures—especially with electric cars—could be difficult. Customers will need to make investment decisions that compare operating cost shifts between unrelated fuel bills (for example, gasoline credit card purchase versus electric bills), and operating costs over time (gas savings / electric cost increases), versus capital investment in cars and charging devices. As the smart grid becomes more sophisticated, utilities may be able to offer customers incentives to enable electric vehicles to connect to the grid (vehicle-to-grid, or V2G), making the vehicles essentially DER devices that supplement the grid. This, in turn, could provide grid-related payments to customers, perhaps with an incentive structure to encourage the purchase of more electric vehicles.

Similarly, utility dispatchers might want to gather data on intermittent, renewable resource generation output and analyze it, along with weather data, so that utilities can develop better renewable resource output forecasting tools as part of their dispatch planning tool boxes.

All of these initiatives are exciting, imaginative, and promising. But we cannot afford to have everyone do everything all at once. The sober realization of needing to budget time and money wisely will bring us back to lessons already learned. In Vermont it has generally been true that efficiency comes first, which means that deploying other resources can best be planned for and afforded to fit the lower total system need. So a consistent method of examining net present value benefits of energy efficiency, demand response, and distributed energy resources within the context of monetized savings and externalities is necessary. Looking at the net present value benefits helps prioritize the alternative steps to intelligently realizing the best performance of the array of EE, DR and DER measures facilitated by the smart grid.

The implementation of smart grid will ultimately affect the level and shape of Vermont's electric load. What will this complex of customer-side dynamics actually mean for utility resource planning? Are these just a nice bunch of interesting activities that are really on the margins of familiar supply strategies, or cumulatively, over time, will they change the dynamics of the market in which utilities and regulators operate? If the latter, how can utilities account for, and perhaps harness these dynamics in their planning processes?

The Vermont mandate for least-cost planning and acquisition of resources is reflected in part in the requirement for the EEU to coordinate a 20-year projection of EE potential with the statewide load forecasting performed by VELCO, the statewide transmission planning entity. As smart grid implementation proceeds in Vermont, the experience with increased EE savings, RE implementation, and DR performance should all be reflected in that planning process.

Conclusions

Vermont requires a least-cost planning approach to meet utility customer needs through law and regulatory requirement. It therefore constitutes a laboratory in which smart grid implementation should take place with the objective to ***enable the greatest efficiency and reliability in the generation, delivery, and use of electricity while minimizing long-term consumer and environmental costs***.

With its unique EEU structure, its commitment to renewable energy acquisition, its statewide transmission and distribution planning system, and its good fortune in securing a statewide ARRA grant for smart grid implementation, Vermont can become a test bed for integrating smart grid implementation with the emergence and enhancement of distributed resource development. It can also use smart grid implementation to recognize, enhance and incorporate the system benefits from those resources into its long-term utility planning process.

In doing so it should be able to demonstrate that intelligent implementation of the smart grid is a legitimate investment of ratepayer dollars.

Vermont will build on the lessons it has learned from a decade of innovative and intensive EE investment to introduce smart grid to customers as another tool to empower them in their search to increase the efficiency and lower the cost of their energy use. If this customer-side dynamic proves to be real, and a multitude of new technologies and services are being offered by the market, how will utilities relate to the customers and to the offerings? Both the EEU and utilities will need to develop the capability to interact with customers in ways that utilities have not had to do as much as other more market-driven businesses. Questions like this, posed by leading thinkers about just what role utilities should play in smart grid implementation will be addressed in a setting that has an independent, not-for-profit entity delivering EE services on behalf of utilities. Vermont will have the option to explore an alternative path between the options of "full utility engagement" and "leaving it to the market."

The realization of the smart grid's benefits will require education of EEU and utility staff and customers in order to effectively use the enormous amount of new data. Some benefits will flow simply due to better information. Some benefits will flow from changes in utility processes such as load and renewable resource forecasting, and interconnection issues for DG. Some benefits will only be realized over a longer time period as consumers make capital investments in new appliances. Some benefits will only be realized with improvements in technology costs and performance, such as plug-in vehicles and stationary battery storage. Some benefits will be realized by lowering total system costs and environmental impacts as a new partnership between customers and electric service providers evolves.