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## Societal Benefits of Smart Grid – An Economics Perspective

By Jagoron Mukherjee



In response to the Energy Policy Act 2005 (EPAAct) Section 1252 many utilities have undertaken aggressive initiatives to drive a “Smart Grid” program. Almost a necessary part of undertaking this exercise is developing a business case to capture the

benefits of Smart Grid capabilities, which typically consist of everything needed to support a) advanced metering; b) AMI communications networks; c) home or personal area networks; d) distribution automation sensors and nodes; and e) data systems and interfaces to legacy applications.

Business cases for Smart Grid are developed to compare the benefits, often incrementally, with the costs of multiple technology options to evaluate and determine the options that provide the

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## Did You Hear? Pertinent Market News Over the Last Month



- The U.S. Department of Energy (DOE) announced the members of its newly-established Electricity Advisory Committee. The 30 inaugural members will serve one- or two-year terms and include some of the nation’s top public and private sector leaders in electricity policy, planning and operations. The Committee was established to provide counsel to the Department on long-range planning and priorities for the modernization of the Nation’s electricity delivery infrastructure. Ralph Masiello, Senior Vice President at KEMA, was among the inaugural members appointed to the Advisory Committee.
- eMeter, a provider of meter data management (MDM) enterprise software to electric, gas, and water utilities, announced the launch of its IntegratedMDM Program with Cellnet+Hunt, CURRENT Technologies, Eka Systems, Elster Group, Sensus Metering, and Trilliant Inc. “The purpose of eMeter’s IntegratedMDM Program is to enable tighter cooperation and future interoperability between a leading independent MDM and multiple AMI technologies,” said Larsh Johnson, eMeter CTO. Under the program, each of the AMI companies independently agreed to cooperate in the integration of their AMI technology with the EnergyIP software.

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## Societal Benefits of Smart Grid – An Economics Perspective

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greatest economic value. In almost all cases, the onus of developing the business case is on the utilities. For utilities, the principal benefits only account for the sum total of what accrues from providing electricity to consumers, i.e., purely from a producer of goods standpoint. Utilities then compare these benefits with the cost of implementing the technical solutions available. To date, the costs for these these solutions are almost entirely borne by the utility<sup>1</sup>.

Typically, the assessment of cost/benefits does not result in a fair comparison. While utilities, as producers, bear almost the entire cost of a Smart Grid implementation, the total economic surplus (or, social surplus) due to a Smart Grid implementation go beyond those accrued to utilities alone. From an economist's viewpoint, substantial benefits accrue to consumers and, more interestingly, to third parties because of positive externalities created from a Smart Grid implementation. Therefore, while the costs are almost entirely borne by the utility at the onset, there are benefits that are not accounted for by the utilities.

This article, presents some of these third-party benefits of "Smart Grid" to highlight why it is important, especially for regulators, to recognize these benefits when considering rate cases. This article also attempts to shed some some light on why it may be good economic policy in some cases for the government to induce support for Smart Grid initiatives through some form of subsidy. Such an approach might help utilities overcome some of the challenges faced in justifying Smart Grid investments, thus benefiting society overall.

### What Are Societal Benefits?

What should be included in the term "societal benefits" is subject to interpretation. In KEMA's experience, we have found that the implementation of a Smart Grid provides direct benefits to the end consumers of the electricity. However, these types of benefits accrue to society in general and are not just limited to the end consumers. Therefore, it is important to make a distinction between "consumer" benefits and "third party societal benefits".

<sup>1</sup> Which eventually wholly or partially get rolled into the rate case that needs to be approved by the local regulators.

### Did you hear?

#### Continued from page 1

- Itron Inc. and Silver Spring Networks have agreed to integrate Itron's OpenWay Advanced Metering platform with Silver Spring's IP-based Smart Energy Networking solution. Under the terms of the agreement, the companies have addressed the technical, functional, and solution delivery issues required to deliver a complete, fully supported Advanced Metering and Meter Data Management Solution with end-to-end IP connectivity.
- In a collaboration with seven utility companies, SAP AG announced a joint effort to integrate AMI with Enterprise technology. The formation of the SAP AMI Lighthouse Council demonstrates a commitment to a new AMI approach that aims to achieve integration of end-to-end processes between the meter and the backend systems and to reduce a company's total cost of ownership for AMI infrastructure. For the past nine months, the SAP AMI Lighthouse Council—comprising CenterPoint Energy, CLP Power Hong Kong Limited, Consumers Energy, Energy East, Florida Power & Light, Oklahoma Gas & Electric, and Public Service Electric & Gas—has been shaping the integration of SAP solutions with AMI solutions for business processes, including customer relationship and billing and enterprise asset management. The SAP AMI Lighthouse Council also includes several strategic vendors, eMeter, Itron and OSIsoft. These vendors offer meter data unification and synchronization solutions that act as a powerful hub for meter and event data between AMI systems and the downstream SAP solutions.

An example of a consumer benefit would be the economic loss a consumer can prevent with better outage management provided by the Smart Grid. In other words, outages may cause consumers to dispose of food in the refrigerator because it gets spoiled due to the electricity outage. If a Smart Grid helps in reducing the frequency and/or duration of the outage, then the avoided economic loss (food costs in this example) is termed as a consumer benefit of the Smart Grid. By comparison, an example of a “third party societal benefit” would be a decrease in environmental degradation because of better electric demand management that results from a Smart Grid. Note that the societal benefits impact everybody<sup>2</sup> regardless of whether an entity is a direct customer of the utility.

### Smart Grid Societal Benefits

Now that we have distinguished “societal” benefits from “customer” benefits, the challenge is how to identify them. Identifying and quantifying societal benefits in any economic valuation is not a trivial exercise. This is because, by definition, valuation of societal benefits relates to what economists call a “social analysis” that relates to human welfare and how livelihoods of different communities are affected. This, in turn, impacts economic performance. The nature of these benefits are difficult to forecast and can very easily be wrongly valued.

Smart Grid is no exception from this standpoint. While there are some obvious social benefits, their relevance and valuation are very specific to the deployment areas and the conditions present within those areas. Utilities typically are not concerned about accounting for these benefits because they do not realize them and hence these benefits do not get reflected in their financial statements. Again, based on KEMA’s experience, we list here some of the societal benefits that are relevant in most Smart Grid deployments. It is important to recognize the caveat that—just like Tolstoy’s, “... happy families are all alike, but every unhappy family is unhappy in its own way”—every Smart Grid deployment will have its own unique list of societal benefits and requires rigorous understanding of community welfare effects in the deployment areas to recognize the value. With that said, here is a sample of typical societal benefits that many utilities will ultimately include in their business cases:

- Decreased electric demand and load that would improve environmental conditions: Smart Grids provide the infrastructure to facilitate load reduction and demand management programs. Each participating customer in this program creates a positive consumption externality that helps in reducing peak loads coincident with the utility’s system peak. Utilities can take advantage of this condition to displace generating units’ run-time, thereby decreasing the amount of pollutants discharged by peaking units. In addition, by automating certain field operations, manual field trips can be avoided, further reducing tailpipe emissions associated with these vehicular trips. Of course, reductions of pollutants have many other benefits that include health benefits and reduced cost. To what extent these additional health benefits and reduced costs ultimately go into a valuation depends on how defensible the assumptions and quantitative data are in providing credible dollar equivalents.
- Benefits that accrue from enabling the efficient and flexible connection of distributed energy resources (DER) devices to lower voltage distribution grids. DER devices include renewable energy (low or zero carbon impact) generation such as wind and photo-voltaic cells and also bulk electricity storage devices that are now becoming available. DER devices break the pattern of ‘economy of scale’ that for 50 years has led to generation connections migrating to central power plants connected to high-voltage transmission grids. Many DER sources are of a scale that makes it economic to connect to distribution grids directly at the distribution voltage level, provided that the existing grids are upgraded to Smart Grids to accept these energy infeeds, collect intelligent information, and handle their variability. The challenge to traditional grid design is most evident where it needs to accommodate microgeneration with its power quality and revenue metering challenges. This aspect is likely to be a key determinant for governments in which carbon reduction targets have been set. Conversely, traditional grids are potentially a significant barrier to achieving such targets if they are not converted to smart operation.

<sup>2</sup> Similar to the characteristics of a public good.

- Benefits that accrue from enabling large-scale DER devices (such as off-shore wind farms, marine energy, and storage systems) to connect and operate efficiently and securely. Large scale DER may connect to transmission grids, but in many circumstances it may be economically and technically attractive to connect them to grids located in coastal areas.<sup>3</sup> This, however, places a new duty on distribution grids, requiring them to operate more like transmission systems with new requirements for power flow control, voltage management, and automatic control actions. Smart Grids architectures and technology solutions are likely to be important enablers here.
- Benefits that accrue from enabling plug-in electric vehicles. A Smart Grid infrastructure will be required to support a fully operational practical implementation of plug-in electric vehicles<sup>4</sup> in the near future. Most of these initiatives are presently in the “concept stage” but many automobile companies are becoming increasingly aggressive in their development activities. The principal idea behind plug-in vehicles is to view an automobile as an electric appliance. To make the concept of plug-in vehicles a pervasive, commercially viable, and operationally practical, requires the development of effective markets and a broader access to these vehicles. At this point, the anticipated benefits of plug-in vehicles are enormous, especially when the reduction of oil consumption, decreased dependence of foreign oil, and the ensuing national security concerns and environmental ramifications are included in the equation.

The above benefits provide a sense of the type of societal benefits that are possible in a Smart Grid program. In addition to these above benefits, there are other, not-so-easily quantifiable benefits. These include benefits like social perception of the utility and the goodwill created in the marketplace. This not only can serve as source of competitive advantage with other utilities, but also impacts seeking corporate funding in equity and credit markets. Typically such benefits create a “bandwagon” effect in the industry that forces other utilities to undertake programs that also create significant economic welfare for the society.

<sup>3</sup> Some of the issues in offshore wind power are documented in <http://www.ocean.udel.edu/windpower>

<sup>4</sup> See GM Chevy Volt, <http://www.chevrolet.com/electriccar/>

### Valuation of Societal Benefits in Smart Grid

Once the applicable benefits for a Smart Grid deployment are identified, the challenge is to value these in dollar terms. It is a known fact in economic analysis that an important consequence of externalities is that, when left unattended, they lead to inefficient resource allocations. Utilities conduct financial valuations of Smart Grid investments based on competitive market allocations such that the investments made are exceeded by the returns, taking into consideration time value of money<sup>5</sup> and cost of capital. However, this allocation may not be optimal for the society at large due to third-party societal benefits. Therefore, when measuring social benefits, we must take into account all the effects that a society experiences from production and consumption of electricity in a Smart Grid deployment, and not only the effects experienced by the utilities that produce electricity and their registered consumers who consume electricity.

As highlighted earlier, there are positive externalities that, if not considered in the valuation exercise, will under-value the benefits of a Smart Grid deployment to the overall society. To value these benefits, oftentimes we encounter enormous quantification challenges that may require complex statistical studies of demographics, health effects, value of life, etc. These quantifications are subject to vast diversity of assumptions that are usually extremely difficult to validate and verify. The encouraging aspect, however, is that there are huge opportunities to leverage from work that is being done in other industries. For example, it might be of interest to an automobile industry to quantify the societal benefits of a fully electric car that would include valuation of reduction of pollution and greenhouse gases. In addition, a public health organization may conduct studies to quantify dollar impacts of quality of health improvement that come from reduced pollution. Data obtained from these industries can be a useful resource in bringing more rigor and accuracy to the quantification exercise and conducting such valuations effectively.

### Subsidy Considerations

So far this article had addressed some of the ways to identify and value societal benefits. In reality, the valuation of societal benefits is of no consequence to the utilities unless there are incentives placed to take credit for these benefits. In other words, the next challenge is how

<sup>5</sup> Usually a form of Discounted Cash Flow is performed.

to implement a policy that is consistent with the valuation of societal benefits. More generally, societal benefits left to electricity-producing utilities will only leave behind a void of an appropriate “market for the positive externalities” that a Smart Grid deployment creates. The absence of such a “market for positive externalities” creates a problem. For example, if there was a market for clean air inside a city, a car driver could be rewarded (through market prices) for polluting less and could potentially be induced into consuming a socially optimal level of gasoline. In such a hypothetical market, marginal social costs of polluting would be equated to marginal social benefits of driving, and social efficiency would be restored. We can apply a similar mindset to think about achieving optimal allocation of resources expended by utilities in Smart Grid programs.

Based on the characteristics of societal benefits that are imminent in a Smart Grid deployment, and the positive externalities mentioned above, we believe that the situation is not very different from the conditions where government support becomes necessary to leverage the full benefits of the Smart Grid. Similar to the market for clear air inside the city that rewards the less polluting car driver, we can think about ways in which a market for utilities that took Smart Grid initiatives would also reward utilities with market prices for creating all the additional societal benefits. Such a scheme would be a more accurate pricing representation of the socially optimal benefits of a Smart Grid deployment. For example, in such an ideal market environment, utilities might receive money for each extra unit of electricity that it pushes through the Smart Grid infrastructure.

While creation of such an “ideal” market is very rarely practical due to high transaction and verification costs, another alternative that is possible is government grant subsidies through policies – both monetary and/or otherwise to utilities to recover part of the costs that relate to societal benefits. A subsidy can serve as a good approximation of the “ideal” market conditions and provide decent incentives for utilities to initiate Smart Grid programs.

### Conclusion

This article has presented some of the societal benefits that are obtained through a Smart Grid deployment. While in most cases, it is difficult to accurately quantify societal benefits, depending on the specific deployment conditions these benefits may be significant in dollar

terms. The lack of a market that rewards such benefits to those who produce – typically utilities that invest in Smart Grid initiatives and the consumers, who consume the electricity from these deployments—may inhibit deployments that are socially beneficial to all. As such, if regulators do nothing to reward utilities for their Smart Grid efforts, many utilities will continually find it difficult to obtain positive returns from Smart Grid deployments. One way regulators and government at large can promote Smart Grid deployments is through a subsidy policy for Smart Grid investments. Such a policy would provide a more realistic valuation to Smart Grid deployments accounting for all the benefits emerging out of the positive externalities, and hence setting the right incentives for Smart Grid investments.

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## Using AMI Data to Improve Direct Load Control Programs

By Christopher Dyson



Utility Direct Load Control (DLC) programs, which have become increasingly popular in recent years, face a number of program planning and evaluation challenges that could be mitigated with access to more detailed customer metering data from Meter Data Management Agent (MDMA) systems. This article

discusses the different ways this MDMA data could be used to improve DLC programs, including more efficient program planning and recruitment, more accurate estimation and verification of load reduction impacts, and less expensive system maintenance. Some of these benefits are being realized now by utilities while others are still in the concept stage.

### DLC Programs in a Nutshell

DLC programs are a key component of the demand response portfolios of many utilities and Independent System Operators (ISOs). They provide valuable peak load relief by reducing customer electricity usage during times of peak system demand. The most common way of doing this is to send a paging or radio signal to either a switch mounted on the compressor of an air conditioner or to a “smart thermostat.” The switch will force the air conditioner to cycle on less frequently than normal or, in

the case of some programs, totally turn off the air conditioner for a number of hours. Smart thermostats will typically reduce air conditioning usage by raising the thermostat setpoints, although some smart thermostats can also cycle an air conditioner like a switch.

While most DLC programs only cycle air conditioners, some programs also cycle electric water heaters and pool pumps. Many DLC programs limit participation to only residential customers while others also recruit small commercial customers. Some programs allow customers to easily “override” a control event by pushing a button on their thermostat, while other programs intentionally make override difficult or impossible. To get customers to participate, most programs pay customers annual financial incentives ranging from \$20 to nearly \$200 per year, depending on the frequency of the cycling they are willing to endure or the size of their air conditioner.

### **Making DLC Program Planning and Recruitment More Efficient**

When it comes to recruiting customers for their DLC programs, most utilities rely on very blunt and often unsatisfactory billing data analysis techniques. For example, most utilities will take monthly residential billing data and then use some kilowatt hour (kWh) threshold as a rule-of-thumb for estimating whether a customer has a central air conditioner or not.

These techniques do an adequate job of finding which customers have central air conditioners. However, what is most important for DLC program managers to know is which customers are using their air conditioners during the key peak days when system capacity is tightest. And more sophisticated DLC program managers want to know how many of these key customers are connected to overstrained feeders or substations where DLC programs could provide valuable targeted distribution system relief.

Having access to detailed customer metering data from an MDMA system would allow utility DLC programs to find and target these key customers. At the same time, the program would save money by not paying financial incentives to “free riders” -- customers who do not use their air conditioners frequently or during the most important periods of peak system usage. By saving money in this way, DLC programs could offer larger financial incentives to recruit these key customers.

### **Making DLC Program Load Reduction Impact Estimates More Accurate**

Knowing how much peak load reduction their programs are achieving is crucial for DLC program managers. In the past, some DLC program could get away with “back of the envelope” calculations – such as 1 kilowatt (kW) of peak load reduction per cycled residential air conditioner – to estimate program load reduction effects. Yet increasingly, ISOs and utility system monitors and planners are insisting on more accurate estimates of these effects. Some ISOs pay DLC programs to serve as spinning reserves or balancing energy resources and they want to be sure that they are getting what they pay for. On summer afternoons when many utility grids are at the breaking points, utility system monitors want to be fairly confident that when they initiate a control event for a 50 megawatt (MW) DLC program, they will be getting 50 MW of peak load relief. Finally, there is growing evidence that these back-of-the-envelope estimates of peak load relief can be very inaccurate.

Yet developing more accurate estimates of DLC program peak load reductions can be very difficult and expensive. To estimate peak load reductions for such programs, evaluators usually have to install data loggers on the air conditioning equipment of a sample of participating customers and then collect these loggers at the end of the cooling seasons. These data are then run through analytical models, such as “kW load” and “duty-cycle” models, to estimate the load reduction impacts of the program. There are significant costs involved in this process including recruiting customers for the measurement and verification (M&V) sample, compensating them for the inconvenience, and then sending out technicians to install and then later retrieve the data loggers.

Access to detailed customer interval meter data from MDMA systems would benefit load reduction analysis in a number of ways. First, it would greatly reduce the cost of analysis since data would be accessed through the MDMA system rather than through expensive field collection processes. Second, it would allow for more flexible sampling designs. The problem with M&V customer samples based on on-site data loggers is that they are static. Most utilities expand their DLC programs in stages over time, and as a program moves into new areas of the utility’s service territory, weather conditions or demographic characteristics may make the old M&V sample unrepresentative of the new program participants. Having access to MDMA data would easily allow sampling of

the new DLC program areas. These data would also allow for more customized sampling strategies such as for certain customer types of interest or customers located in the area of certain vulnerable feeders or substations.

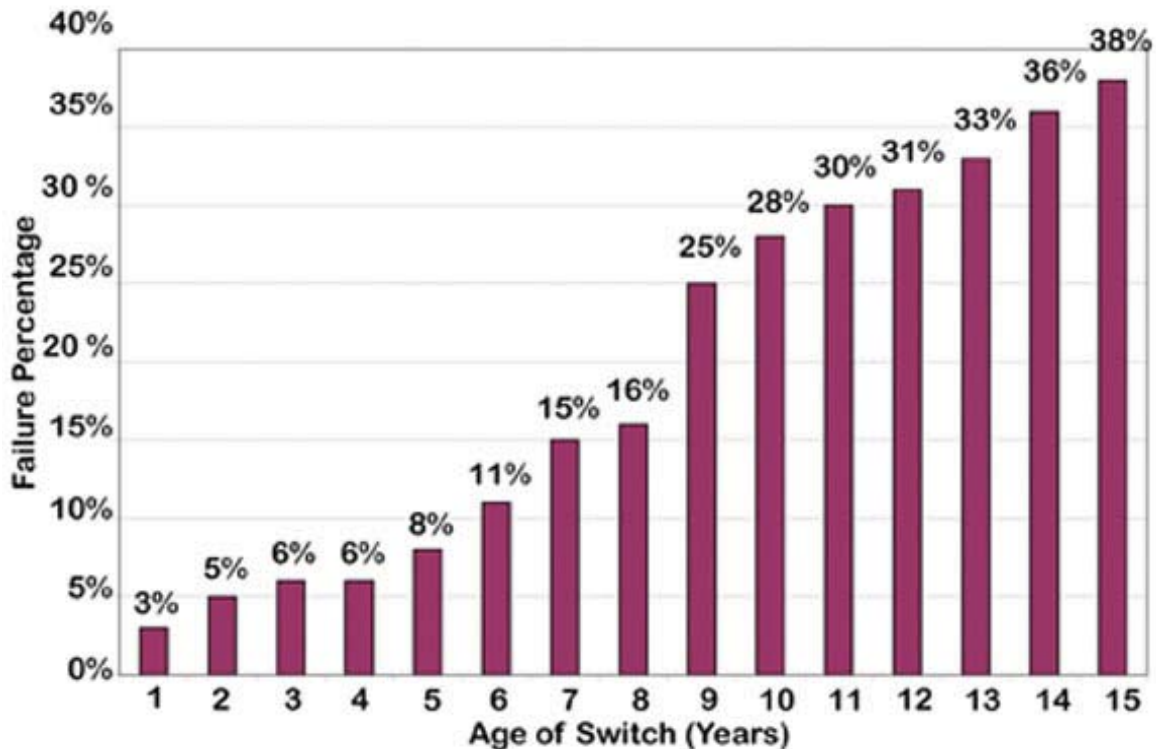
However, in order to effectively replace in-field data loggers, MDMA systems would have to be able to provide data of the same quality as these loggers. Currently, relatively-inexpensive data loggers can store up to a year of one-minute amp readings for each customer. Certain analytical methods for estimating DLC program load reductions – such as “duty cycle” models – are most effective when using data over these long time periods and at these precise time intervals. Another potential concern is that while data loggers provide amp readings for only the air conditioners, most MDMA systems would likely provide less precise household-level data. However, recent analyses by KEMA indicate that household level metering data can be reliable as inputs to these analytical models.

### Xcel Energy Case Study: Reducing DLC Program System Maintenance Costs

While the previously discussed benefits of MDMA systems for DLC programs are only at the concept stage, at least one utility -- Xcel Energy -- has been using its Automated Meter Reading (AMR) system to produce tangible benefits for its DLC program. Xcel has leveraged the data from its AMR system to make its system maintenance process much more efficient and cost effective.

Air conditioner control switches break down over time and if older DLC programs do not do regular maintenance, they are in danger of losing much of their peak load reduction capacity. However, DLC program managers face the additional challenge of not knowing which of their switches are not working. Due to cost constraints, many DLC programs have installed control devices that lack two-way communication capabilities. Therefore, there is no easy way for program managers to know how many of their devices are receiving the activation signals. Not surprisingly, switch failure rates increase as the switches age. Yet many legacy DLC programs do not have reliable records of the age of their devices. And even when they do have reliable records, as Figure 1 shows, failure rates for switches as old as 15 years are still below 40 percent. This means that, wholesale replacement of switches of a certain age may not make economic sense.

**Figure 1 - Failure Rates for Air Conditioner Control Switches as They Age**



Source: Xcel Energy

When Xcel Energy first initiated maintenance procedures for their Minnesota residential DLC program, Saver's Switch, in 1998, their maintenance strategy was based on the age of the switches. The utility would send out technicians to the older switches in order to inspect wiring, to inspect the external and internal condition of the switch, and to run control test simulations to verify the functionality of the internal components.

Yet this age-based maintenance strategy proved to be very costly. Since only a minority of the older switches would be failing, the Xcel Energy technicians would have to make multiple visits to the same switch until it failed. Although this age-based maintenance strategy did discover 4,000 bad switches and recovered 4.5 MW of lost load reduction capacity, the field work took 9 months and the cost per recovered kW was \$599.

Between 1997 and 2001, Xcel Energy implemented a CellNet fixed wireless AMR network with 1.4 million electric meters installed in parts of Minnesota and the Dakotas. The Saver's Switch program staff decided to see whether or not this new AMR system could help reduce the program maintenance costs. In 2001 they developed an AMR-based maintenance strategy. They selected a test group of program participants, pre-arranged a modified AMR schedule to capture the electric usage data from the customers in this test group, scheduled a test for a day with weather similar to a typical control event, and then initiated the test control event. After this, they analyzed the meter data from the AMR system to see which switches had reacted properly to the

control event. Finally, they forwarded the list of failed switches to their field technicians for site inspection and switch replacement.

This new AMR-based maintenance strategy proved to be much more cost-effective than the age-based maintenance strategy. As Table 1 shows, the Summer Saver's program was able to test many more switches and annual time in the field was less than half of what it once was. The overall cost per kW of recovered load reduction capacity was about one quarter of what it once was.

**Table 1 - Comparative Maintenance Metrics Age-Based vs. AMR-Based Strategies**

Maintenance Metric	Age-Based Maintenance Strategy 1998	AMR-Based Maintenance Strategy 2001-2005
# of switches visited/tested	44,000	275,000
# of switches replaced	4,000	45,000
Part of switch replaced	Entire control switch	Only circuit board in most cases, upgraded technology
Recovered load reduction capacity	4.5 MW	48 MW
Duration of field work (per year)	9 months	4 months
Cost per kW of recovered load reduction capacity	\$599	\$153

Other utilities that have both AMR systems and DLC programs are now looking to adopt similar AMR-based maintenance strategies. For example, Pacific Gas and Electric (PG&E) is in the midst of large expansions of both its AMR systems and its DLC program. By the end of 2011, it expect to deploy about 10.3 million new "smart" meters and by the end of 2010 it also plans to have about 400,000 customers in its SmartAC DLC program. For instance, PG&E is looking to adopt an AMR-based maintenance strategy for the SmartAC program that is similar to the one that Xcel Energy had adopted.

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## A Conversation with John Clark, CEO of V2Green

By Will McNamara



**McNamara:** As an introduction, please provide a short overview of V2Green (when it was formed, your business model, etc.)?

**Clark:** V2Green builds and deploys Smart Grid solutions for utilities. Our technology establishes intelligent, two-way communication between

the electrical grid and distributed power resources. The flow of electricity to and from significant sources of load, power storage, and generation can then be adaptively managed to avoid damaging grid stress, cost-effectively produce essential grid services, and increase the integration of renewable energy in power generation.

Plug-in electric vehicles (PHEVs) are a particularly valuable power resource, at once representing a source of load, a means of storing power, and offering the ability to return energy to the grid when needed. Fully realizing the economic and environmental potential of PHEVs requires control over the power flow. V2Green technology allows utilities to manage vehicle-charging behavior, within parameters set by owners. In real-time, utilities are able to increase charging levels when renewable energy, such as wind or solar power, is available and also delay or slow charging during peak periods, thereby minimizing demand spikes and the need for expensive, carbon-intensive energy generation. By managing the power flow, the existing grid infrastructure will be able to support the wide-scale adoption of PHEVs and utilities will have the ability to cost-effectively utilize the vehicles as storage and in the production of critical grid services such as spinning reserves or system regulation. Perhaps most importantly, V2Green technology facilitates the increased integration of renewable power in energy generation and accelerates the adoption of PHEVs, reducing the greenhouse gasses that cause climate change.

V2Green was founded in late 2006 on the belief that electricity will play a vital role in addressing the twin crises of climate change and dependence on foreign oil. The company is based in Seattle and led by an experienced team of hardware, software, and communication industry veterans.

**McNamara:** For someone just becoming familiar with PHEVs, please provide an overview of how the vehicle-to-grid (V2G) technology actually functions.

**Clark:** Well, the V2Green System is an integrated client-server solution. The V2Green Server communicates with distributed power resources, controlling the timing and pace of the energy flow to and from the electrical grid and managing the information generated by these activities. In the case of PHEVs, in-vehicle clients consisting of electronics and embedded software transmit commands to the car's power electronics and communicate performance data back to the V2Green Server via cellular, WiFi, utility AMI networks, or other communication methods. The V2Green System also delivers online data collection and aggregation, allowing analysis of vehicle performance, efficiency and driver behavior.

Acting as a power flow management platform, the V2Green Systems allows utilities to employ charging control scenarios, including smart charging and V2G.

- **Smart Charging.** Managing the flow of power to PHEVs enables utilities to control the load impact on the grid and utilize the vehicles as distributed energy storage. This minimizes the need for expensive infrastructure investments, reduces operating costs, and increases the integration of renewable energy in power generation. Apart from the V2Green System, no additional investment in hardware or software is required.
- **Vehicle to Grid (V2G).** The V2Green System also allows utilities to manage the flow of energy back to the grid when necessary. In the case of vehicles, this reversed flow is known as V2G. Broad, commercial deployment of V2G lies in the future, when both PHEVs and grid-charging sites have the ability to flow power bi-directionally. In 2008, Xcel Energy will deploy the V2Green System in the first real-world field trial of V2G technology, demonstrating both its capabilities and economic value.

**McNamara:** Does the V2Green System assume a standard communications interface that a utility must have in place to be functional? How does V2Green's software interface with other load-control or metering technology that a utility might have in place (in other words does V2Green promote interoperability with its products)?

**Clark:** Essentially, V2Green System is communications agnostic. Our technology supports a wide variety of communication methods, including the following:

- Cellular data networks
- WiFi bridging to the internet
- HomePlug bridging to the internet or AMI networks
- Zigbee bridging to an AMI network.

V2Green is a strong believer in standards and interoperability, believing both will be key to delivering successful solutions to the marketplace.

**McNamara:** In the alliance between electric utilities, tech companies, and automakers that are joining forces to develop “smart-charging,” what do you think each sector brings to the table?

**Clark:** Smart charging allows the majority of the broad social and economic benefits promised by PHEVs to be realized. The utilities, experiencing reduced operating costs and new electricity revenue, will encourage PHEV adoption through economic incentives and customer-friendly charging tariffs. The resulting lower cost of “fuel” will lower the cost of ownership and drive plug-in vehicle sales, encouraging automakers to further their investments in clean-energy transportation. The net benefit includes reduced reliance on imported oil, lower fossil fuel consumption, and a decrease in the greenhouse gas emissions that cause climate change.

Today, as many leading utilities begin to undertake PHEV/smart charging field trials, the automotive industry is engaged in setting standards for vehicle-grid communication that will guide vehicle design and innovation in the future. V2Green is focusing decades of experience in hardware, software, and communications on bridging the gap between the grid and plug-in vehicles, as well as other power resources.

**McNamara:** Why are we seeing more electric utilities jump on the PHEV bandwagon now?

**Clark:** Plug-in vehicles will be commercially available in less than two years. Major auto manufactures, including General Motors and Toyota, have announced plans to introduce PHEVs by 2010. Leading electric vehicle manufactures such as Tesla Motors, Think Global, and Zenn Motors are expected to have cars on the road before then.

These vehicles, essentially mobile batteries, represent a significant opportunity for utilities. Assuming their interaction with the grid can be managed, PHEVs represent a new, distributed power resource that can be used to store renewable energy and cost-effectively produce grid services. However, even small clusters of uncontrolled vehicles charging at peak periods could significantly stress the distribution system and trigger major infrastructure investments.

Many leading utilities across the nation, including Xcel Energy, Austin Energy, and Seattle City Light, are initiating PHEV field trials and demonstration projects to better understand the impact plug-in vehicles will have in their service areas. Given that each grid has unique challenges and constraints, particularly at the distribution level, utilities are eager to inform their strategic planning process with relevant experience and data.

**McNamara:** Some utilities may be concerned about the strain that charging all these PHEVs might put on the electric grid. What would you say to alleviate those concerns? Do you believe there should be a “charging queue” so that the impact on the grid is minimized?

**Clark:** Many of the nation’s leading research institutions, from the National Renewable Energy Laboratory (NREL) to the Pacific Northwest National Laboratory (PNNL), have assessed the impact of PHEVs on the electrical grid, reaching optimistic conclusions. NREL concluded that “no additional capacity would be required for even a massive penetration of PHEVs” and PNNL asserted that “84 percent of the cars, pickup trucks and sport utility vehicles (SUVs) could be supported by the existing infrastructure. This suggests a gasoline displacement potential of 52 percent of the nation’s oil imports.”

Intrinsic to these PHEV studies is the critical, yet under-emphasized, assumption that the charging behavior of these vehicles, and thus their impact on the existing grid, will be controlled. NREL suggests charging will occur overnight, PNNL assumes the entire PHEV load will be “managed to fit perfectly into the valleys of load demand without setting new peaks,” and the Electric Power Research Institute (EPRI) asserts that PHEVs will significantly reduce greenhouse gas emissions given the existence of “programs to actively manage the charging load.”

V2Green provides the power flow management required for the existing grid infrastructure to support the wide-scale adoption of PHEVs.

**McNamara:** What about software that would synchronize PHEVs with hourly electricity prices? Is that something V2Green is offering?



John Clark  
CEO, V2Green

**Clark:** Yes. It is possible for the V2Green Server to receive economic inputs from the utilities, allowing electricity pricing to be taken into account when scheduling and managing the flow of power to PHEVs. Matching vehicle charging behavior to off-peak pricing will result in a savings on “fuel” that we

anticipate will be passed on drivers for participating in smart charging programs.

**McNamara:** V2Green recently announced a deal to monitor plug-ins used by the Idaho National Laboratory, and the company is also working with utilities in Denver and Austin on managing timing and pace of vehicle charging. What is the significance of those partnerships?

**Clark:** Managing the flow of power to a PHEV is difficult. Unlike an air conditioning system or a power storage system, plug-in vehicles intermittently connect to the grid and their mobility means they connect from multiple locations. Additionally, a PHEV’s is uniquely dependent on human behavior. Having solved the challenge of controlling the power flow to PHEVs, it is easier for V2Green to provide management solutions for other distributed resources.

Our engagements with utilities and leading research institutions provide real-world experience and data to inform our continued product development efforts. Each field trial will demonstrate the effect of PHEVs on the grid infrastructure and the potential benefits of power flow management; however, each investigation is taking a different approach.

- Throughout their Midwest service area, **Xcel Energy** will be exploring the potential impact and benefit of both smart charging and V2G – controlling the flow of power to and from six converted Ford Escape Hybrids.

- **Austin Energy** is focused on controlling charging behavior to capture the West Texas wind that typically blows overnight. They are investigating using smart charging to increase the integration of renewable energy in their power generation operation and employing PHEVs in the production of critical grid services, such as system regulation and spinning reserves.
- **Seattle City Light** is deploying 13 converted vehicles to understand the impact of deploying a PHEV fleet in an urban environment and potential economic advantages of smart charging.
- **Idaho National Labs** is deploying the V2Green System in 57 converted PHEVs, specifically for data collection and analysis of vehicle performance and driver behavior.

**McNamara:** The concept of using PHEVs as a back-up power system for a home or for the power grid may be difficult for the general public to grasp. How do you think that PHEVs will really change our day-to-day lives?

**Clark:** A significant reduction in the cost of their daily commute will be the most immediate day-to-day change in the lives of PHEV owners. Conservatively, a PHEV will be able to travel between 20 to 40 miles using electricity at an anticipated “fuel” cost of less than \$1 a gallon. Most PHEV drivers will be able to drive back-and-forth to work without burning fossil fuels. With \$4 per gallon gasoline prices on the horizon, this represents a significant cost savings. Conceivably, PHEV drivers will also feel a sense of empowerment, having made a significant commitment to reducing the tail-pipe emissions that result in climate change.

Over time, the wide-scale adoption of PHEVs has the ability to reduce the country’s dependence on foreign oil and improve our overall energy security.

**McNamara:** Is there a distinction between PHEVs and pure electric cars?

**Clark:** A plug-in hybrid electric vehicle is equipped with a combustion engine, burning fossil fuels, and an electric motor. When the charge is depleted in the vehicle’s battery, the combustion engine will seamlessly engage. For the driver, the primary difference between today’s hybrid vehicles and a PHEV will be increased distance they can travel using electricity as fuel.

Fully electric vehicles are fueled solely by electricity, equipped with electric motors and larger battery packs. They will have a significantly greater all-electric range, traveling 100-200 miles per charge. Unlike PHEVs, fully electric vehicles will require recharging to travel further if they've depleted their charge.

**McNamara:** What impact do you think PHEVs will have on home area networks (HANs)?

**Clark:** We anticipate PHEVs will be one of many distributed power resources managed via HANs as the technology becomes available in conjunction with the rollout of utility AMI networks. The V2Green System is able to control the power flow to both PHEVs and fully electric vehicles through an AMI/HAN network just as easily as any other communication path.

**Clark:** We anticipate the price of both conversion kits and PHEVs to fall over time as the technology becomes more widespread and economies of scale come into play.

**McNamara:** As always, California seems to be a leader, with its recent regulation requiring automakers to put 58,333 PHEVs on the state's roads from 2012 through 2014. What do you think of that regulation, and should other states impose similar mandates?

**Clark:** In general, V2Green supports the adoption of PHEV mandates by the states, believing they will accelerate the availability of plug-in vehicles. However, we are disappointed in the recent ruling by the California Air Resources Board (CARB). Rather than introducing a new, wide-reaching mandate for the availability



**McNamara:** Prototypes of PHEVs suggest 70 mpg to 120 mpg is possible. What has been your experience at V2Green?

**Clark:** Yes, we have seen PHEVs deliver the extremely attractive mileage you reference.

**McNamara:** What are you seeing in terms of projected cost of a standard PHEV?

of PHEVs, CARB chose to modify California's existing Zero Emission Vehicle (ZEV) mandate, reducing both its strength and magnitude.

**McNamara:** Great talking with you. Thanks for your time, John.

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## Then and Now: Current Trends for HAN Integration Reveal Slow (But Promising) Growth

By Mark Knight (KEMA) and Matthew Spaur (Itron)



This article recalls another article written over six years ago by one of the authors while working for a start-up company developing residential gateway applications. That article centered on ways that residential gateways could be used for distributed load curtailment. Six years ago, this was a promising technology but without any wide-scale adoption. This current article looks at some of the expectations from early 2002 and compares them to what is happening today. In that previous article, it was said that,

*"while load curtailment has been around for many years, price-responsive demand programs are growing in popularity. Yet for both of these there is a huge untapped market just waiting for the right cost benefit model."*

Six years later and still today we are seeing more attempts to manage load both in terms of load reduction and load shifting through time of use (TOU) rates and smart meters coupled with advanced metering infrastructure (AMI) that are helping to make this possible. The previous article also stated that

*"price responsive demand is an attempt to reduce price through a reduction in load. While it may also benefit reliability, this is not the motivation."*

That last sentence is worth a whole discussion of its own and that will be addressed in a future article, but the previous article also went on to state that

*"A large customer with localized load can help balance local demand with supply. However, benefits on a wider scale are limited by transmission and distribution system capacity. The capacity of the network is constrained by engineering limits. Typical load curtailment is a bit like a doctor treating a patient with high blood pressure and clogged arteries by*

*reducing blood pressure in one arm and hoping it will provide the necessary benefit to the rest of the body.*

*What is really needed is the ability to aggregate multiple distributed loads by allowing each metered load sink to be a member of more than one load group. This requires load to be situated across the network for optimal benefits... The ability to aggregate multiple loads would provide the capability to provide a flexible load reduction mechanism that could be used to support load curtailment and price-responsive demand."*

At the time that the previous article was written, the promise seemed great, but the realization of these schemes has been slow to materialize. In recent years, EPA 2005, California, Italy, and Ontario are among the factors that have helped to make these possibilities more of a reality through widespread implementation of interval metering of residential customers.

Interval metering through smart meters is being implemented, among other reasons, to support TOU rates. But, when coupled with an ability to integrate with home area networks (HANs) and smart appliances, the dream of distributed load management is much closer to being a reality.

The 2002 article wrote that

*"Grouping residential and small commercial loads both regionally and locally could allow the emulation of current curtailment programs. It would also have the capability to provide distributed load curtailment by reducing load that has been aggregated from geographically dispersed locations... if enough of these customers had interval metering with automated meter reading (AMR), their load could be aggregated to a sufficient level."*

This is the type of service being provided by EnerNOC, Comverge, and others for commercial customers where load reductions are bid into the market to offset increased generation requirements. Of course, without smart appliances, the ability to influence reductions in residential customer load depends on voluntary participation or the ability to cycle air conditioners, pool pumps, or other

devices that consume high loads. Now, however, smart appliances are becoming a reality. Much research has been done on the adoption and use of these devices for load reduction when coupled with TOU rates, such as the Woodbridge project by Whirlpool in 2003-2006.

Underlining the benefits of load reduction, the Energy Action Plan adopted by the state's energy agencies in California places conservation and energy efficiency first in the loading order of energy resources because they are the least expensive and most environmentally protective resources. This is described in a Staff Report by the California Energy Commission to which KEMA provided input.

### **Itron's Experience**

Going back to 2002, the startup became Lanthorn Technologies after the author left the company. Itron, a leading supplier of metering-related solutions to utilities, recognized a good deal of promise in the technology and invested significantly in the company between 2002 and 2004. Although Lanthorn went out of business in 2004, Itron has continued to pursue the promise of this technology. We are seeing increasing interest in home area networking and smart appliances today, with smart meters as the gateway to the home.

The trend towards balancing load through demand response is one factor that led Itron to develop OpenWay®, their AMI solution for electricity and natural gas. Like many in the industry, Itron views AMI as a combination of smart meters and two-way communication networks that offers all the operational efficiency of AMR plus pervasive demand response and energy management along with support for a Smart Grid.

In developing OpenWay, Itron took a radical departure from their existing AMR solutions. They decided that OpenWay would be built on open standards, with a different type of network communications architecture. These decisions meant that, at least initially, OpenWay would not offer a migration path from existing Itron AMR solutions to the new AMI platform. The market was asking for an AMI solution built around a two-way communication network based on open standards. That is what Itron delivered for AMI.

Itron decided to support residential demand response by including ZigBee® open standard wireless networking in every OpenWay CENTRON®. ZigBee is the only global wireless communications standard offering easy to use low-power, secure, reliable, self-forming, and self-healing mesh networks. With a ZigBee link reaching into the home, utilities can send price signals directly to devices. Those devices can then respond to the signal according to the settings and preferences programmed by their owners.

Itron chose this approach, in part, to help foster a marketplace for innovation in smart energy devices. Utilities and their customers want a choice when selecting energy devices. To help start this new marketplace for energy devices, Itron formed a strategic, but non-exclusive, partnership with Comverge to offer programmable communicating thermostats that can deliver on the promise of residential demand response.

Technologies like ZigBee provide the basis for HANs, which allow multiple devices in the home to communicate and work in concert to automate energy management without sacrificing comfort or convenience. For instance, a utility price signal can travel from a meter into the home through a ZigBee link. Inside the home, a thermostat or in-home gateway receives that signal and passes it along to other appropriate devices to respond.

### **Interoperability & Demand Response**

The OpenHAN industry group has worked to develop a specification of what a HAN should offer in terms of capabilities and interoperability. Itron actively participates in the OpenHAN work, as part of their dedication to open standards for OpenWay.

Southern California Edison (SCE) validated the OpenWay solution by selecting it to automate over five million meters throughout their service territory. In truth, SCE's vision and specifications for an AMI system informed much of the OpenWay design. SCE has also been instrumental in guiding the OpenHAN effort to define what a home-area network should deliver for energy management.



A large part of SCE's business case for deploying an AMI system across its Southern California service area rests on the benefits of residential demand response. SCE plans to derive 1,000 MW of new demand response capacity from the utility's AMI deployment. That level of demand response will help SCE manage peak energy demand much more effectively. Better management means better system reliability, less need for new peaking power plants, and less need to buy expensive peak power on the open market.

Demand response doesn't take place solely in the home, however. The entire energy delivery system needs to support demand response from sending price signals to measurement and verification of demand reductions to billing calculations based on demand response programs. This pervasive impact of demand response programs is another reason that Itron built OpenWay on open standards. Those standards provide easy integration between new AMI technology and existing utility infrastructure such as CIS and billing systems. Aside from ZigBee, other standards such as C12.19, C12.22, TCP/IP, Web Services, and XML all play a role in uniting the energy delivery system into a responsive network with two-way communications. Itron and OpenWay support all of these standards and more.

There are also many other factors all converging to make HANs attractive propositions in addition to the development of standards and emerging new technologies. There is the increased availability of broadband access (including through the power line), the convergence of other services, e.g. cable, phone, and internet, and a much greater availability and public awareness of home networking thanks to in-home technology such as wireless networking, networked printers, and network storage, all of which many of us already have in our homes.

Therefore, today we are much closer to being able to realize the benefits of distributed load control and HAN is generating more and more interest on the residential side. For commercial and industrial customers we have also seen the establishment of commercial organizations such as EnerNOC, who sell "negawatts" into the system, and Converge with their "smart megawatts" to reduce generation and reduce harmful emissions. Six years on, the future is here today.

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1. Load Curtailment, Mark Knight, Energy Markets, February 2002.
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Matthew Spaur works in business development for Itron, focusing on advanced metering and Smart Grid applications. In his four years at Itron he's also worked in software marketing and corporate marketing. He holds a masters from Eastern Washington University and previously spent 11 years at Microsoft in a variety of roles.

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