THE SMART GRID:
A PRAGMATIC APPROACH

A "State-of-Play" Discussion Paper Presented by the Canadian Electricity Association

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

The electricity sector has become the focus of heightened policy interest in Canada, as elsewhere, in the context of escalating concerns over emissions, security, and energy demand growth. In this elevated policy context, the smart grid has been much discussed often as a panacea rather than simply the continued maturation of an electricity network that was already on a steady path to automation—and indeed already had some "smart" components.

Unfortunately, this has led to heightened expectations by customers that have yet to be met. As such, the industry finds itself at a crossroads between initial enthusiasm based on industry excitement, and the more pragmatic, cautious path forward. It simply cannot be overemphasized: without customer consent, the deployment of the smart grid will surely stall.

To progress towards a smart grid roll-out that is both valuable to stakeholders and widely accepted by customers it is important to understand exactly what a smart grid is. There are numerous definitions, but the electricity industry in Canada sees the smart grid as a suite of information-based applications made possible by increased automation of the electricity grid, as well as the underlying automation and communication infrastructure itself. As the underpinning to the business case, the various applications and automation technologies must deliver on one or more of the following benefits: grid resilience, environmental performance, or operational efficiencies.

The transition to a more automated grid—in pursuit of the above mentioned benefits—entails changes and enhancements across the grid value chain, from how the electricity supplier operates, to how the network is structured, to how the end user interacts with the grid infrastructure. These changes can be organized into five categories, and constitute the smart grid's key characteristics or capabilities: demand response, facilitation of distributed generation, facilitation of electric vehicles, optimization of asset use, and problem detection and mitigation. Hard infrastructure, such as smart meters, network devices, energy storage, and smart appliances, as well as soft infrastructure such as interoperability standards, cyber security protocols, the 1.8 Ghz spectrum, and stakeholder engagement, represent the building blocks that support the five key capabilities. Interwoven into each of these characteristics and building blocks is the theme of improving the customer experience through new service offerings, reduced delivery charges for those offerings, and faster response times.

With this understanding of what constitutes a smart grid, it is important to review growing pains and early lessons learned in order to assess how, as a sector, we must adapt to move forward. Security, privacy, implementation cost and stakeholder engagement have each been areas of concern to date; vendors, policy-makers, regulators and utilities must work together to ensure that our collective shareholder, the customer, recognizes the full worth of each installed component of the smart grid.

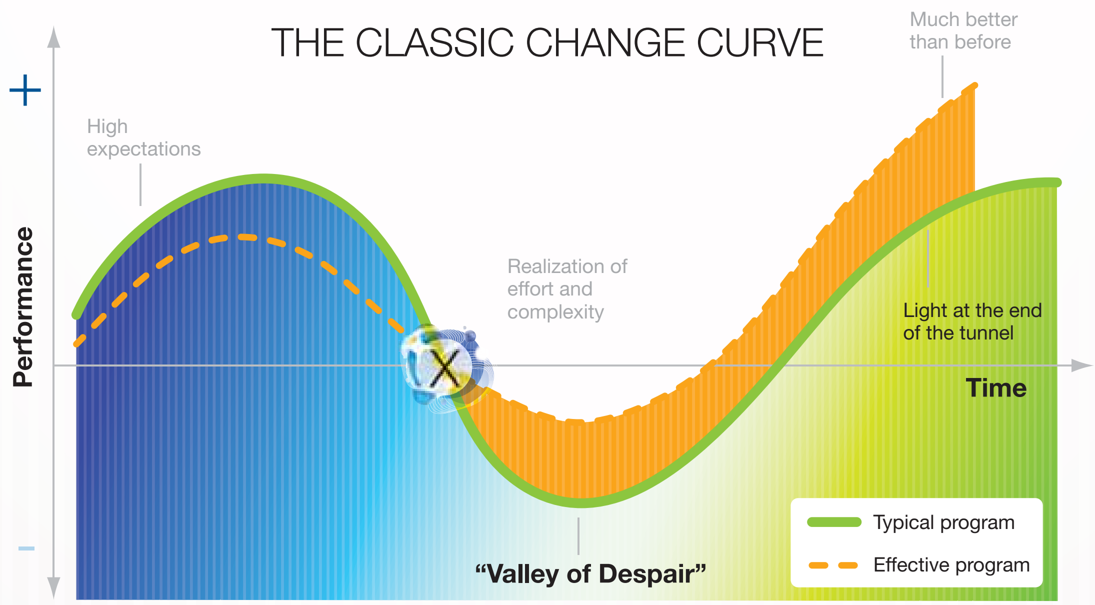
Generally speaking, the business case for automation has been proven time and time again, and the electricity industry will gain value from automation as well. The remaining question marks surround not *if,* but rather *which technologies, at who's pace, and at what level of public acceptance*. This paper provides the basis for discussion of how we will collectively move from "high expectations" through "the valley of despair" and onto "continuous improvement"; this ought to be done through a process of confronting reality, crafting a vision, and communicating belief in the process.

INTRODUCTION

To some, the term "smart grid' has already overstayed its welcome. Governments in some jurisdictions, such as Ontario, are having to defend their mandated smart grid roll-outs to a public that is increasingly wary of smart meters and time-of-use pricing, is pushing back against near-by distributed generation projects, and has been slow to show interest in electric vehicles. In addition, electricity regulators are cautiously examining the costs and benefits to electric utility customers, and utilities are examining whether the smart grid equipment available today is quite as "smart" as it is touted to be. Therefore, despite theoretical benefits and some early demonstrated successes, the smart grid appears to be at a critical phase in its development. A change management consultant with a flair for the dramatic might say that at least some aspects of the smart grid concept have entered "the valley of despair" which often follows "high expectations" and precedes "continuous improvement" on a typical graph showing the phases of change.

HIGH EXPECTATIONS

As a concept, the smart grid is intuitive and elegant. Digitization has drastically changed the world of telephony, a mechanic more often wields a diagnostic computer than a wrench, the internet has transformed shopping, and email has replaced the hand-written memo. It was only a matter of time before the electricity grid, recognized by many as the world's biggest machine, was automated as well.



In addition, and more importantly, the smart grid provides a plausible response to a very important question: how will we, as a society, bring together the elements required to ensure that our energy use is sustainable for future generations. Among other benefits, the smart grid facilitates the integration of wind and solar and geothermal; it enables a car to be powered by (mostly) hydro power rather than conventional fossil fuels; and it gives customers the knowledge and tools to make the right choices. What's not to like?

This view has been promoted most eagerly by the vendor community that has developed the equipment and software to make it happen. In one recent ad, a scarecrow dances on power lines singing the Wizard of Oz classic "If I Only had a Brain"; similarly, President Obama has been asked to "adopt the goal of giving every household and business access to timely, useful and actionable information on their energy use... [in order to] unleash the forces of innovation in homes and businesses... harness the power of millions of people to reduce greenhouse gas emissions - and save consumers billions of dollars."[1] Now *that* is marketing.

Governments themselves, such as the current Obama administration, have also played a role in the cycle of high expectations, touting smart meters as a way for customers to save money (rather than shift consumption to better optimize generating assets), and assuming that grid advances would allow for the connection of a near unlimited supply of variable generation. Some utilities, as well, underestimated the volume and precision of communication and relationship building required to change a customer base of passive electricity users into active market participants.

REALITY CHECK

This push-back by the customers is what has led, for some technologies in some jurisdictions, to the rather hyperbolically named "valley of despair". Questions have arisen about the benefits of the smart grid by those who pay the rates, and as such a closer examination of the underlying business case appears to be underway, industry-wide.

This is not a new phenomenon; large movements of technological change are almost always over-promised and under-delivered in the first several years of implementation. An obvious illustrative example is the internet; early expectations were that online shopping would quickly replace bricks-and-mortar stores, a stock bubble formed, expectations were adjusted to the realistic pace of change, and the bubble burst. This is not to say, of course, that online shopping was conceived on a false premise. When the dust settled, the strong online applications remained and a better understanding of the space has led to a process of continuous improvement. The speed at which the utilities and other stakeholders translate lessons learned by the front runners to best practices for all will determine how quickly the smart grid moves towards that final, steady, upward slope.

CONTINUOUS IMPROVEMENT

Just as with online shopping, at the heart of the smart grid is a rational concept with real value. Increased automation of the electricity grid will improve its performance and allow for the integration of various applications and usages. That improvement, however, will depend on a myriad of utility-specific factors including the energy supply mix, the infrastructure already in place, and their relationship with their customers.

This paper seeks to explain the broad functionality of the smart grid as it pertains to Canada and the benefits that it affords to both customers and grid operators, while also setting the stage for all stakeholders to work together for the continuous improvement of the smart grid. Because call it what you would like, the smart grid is moving forward—and that's a good thing.

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[1] *A Letter to the President of the United States.* April 5, 2010. Google Inc. et al.

I. DEFINITION AND OBJECTIVES OF THE SMART GRID

A) Definition

The smart grid represents an array of visions to an array of stakeholders. Due to this variance, as well as the complexity of the technologies involved, it is not surprising that the smart grid has given rise to a number of definitions and explanations. Here are three examples of descriptions recently published by trusted authorities:

» "A smart grid is a modern electricity system. It uses sensors, monitoring, communications, automation and computers to improve the flexibility, security, reliability, efficiency, and safety of the electricity system."[2]

» "The smart grid takes the existing electricity delivery system and makes it 'smart' by linking and applying seamless communications systems that can: gather and store data and convert the data to intelligence; communicate intelligence omnidirectionally among components in the 'smart' electricity system; and allow automated control that is responsive to that intelligence.[3]

» "An automated, widely distributed energy delivery network, the Smart Grid will be characterized by a two-way flow of electricity and information and will be capable of monitoring everything from power plants to customer preferences to individual appliances. It incorporates into the grid the benefits of distributed computing and communications to deliver real-time information and enable the near-instantaneous balance of supply and demand at the device level."[4]

From these definitions key themes emerge: communication, integration and automation that is sustainable, economic, and secure. Incorporating these themes, this paper offers the following concise definition of a smart grid: the smart grid is a suite of information-based applications made possible by increased automation of the electricity grid, as well as the underlying automation itself; this suite of technologies integrates the behaviour and actions of all connected supplies and loads through dispersed communication capabilities to deliver sustainable, economic and secure power supplies. From this definition, the key objectives of the smart grid come into view.

B) Objectives

Drawing on the above definition, smart grid investments should support at least one of the following objectives: increase grid resilience, improve environmental performance, or deliver operational efficiencies including workplace safety.

RESILIENCE

Grid reliability is non-negotiable. A 2004 study by researchers at the Berkeley National Laboratory found that power interruptions cost the American economy $80 billion per year; other estimates are as high as $150 billion per year.[5] Moreover, the North American Electric Reliability Corporation has noted that "reliably integrating high levels of variable resources—wind, solar, ocean and some forms of hydro—into the North American bulk power system will require significant changes to the traditional methods used for system planning and operations."[6] Proponents claim that the smart grid will facilitate these changes by enabling additional dispersed supply and by enhancing corrective capabilities where problems occur. While the smart grid may indeed enhance security in some aspects, however, the additional information technology of the smart grid may also render it more vulnerable than the conventional grid to cyber attacks, and as such may pose a very real threat to reliability.

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[2] Paul Murphy et. al., *Enabling Tomorrow's Electricity System: Report of the Ontario Smart Grid Forum*, http://www.ieso.ca/imoweb/pubs/smart_grid/Smart_Grid_Forum-Report.pdf (September, 2010)

[3] Miles Keogh, *The Smart Grid: Frequently Asked Questions for State Commissions*, The National Association of Regulatory Utility Commissioners, May 2009, p. 2, http://www.naruc.org/Publications/NARUC%20Smart%20Grid%20Factsheet%205_09.pdf, (June, 2010)

[4] *The Smart Grid: An Introduction*, U.S. Department of Energy, http://www.oe.energy.gov/DocumentsandMedia/DOE_SG_Book_Single_Pages(1).pdf (September, 2010)

[5] Kristina Hamachi LaCommare and Joseph H. Eto, *Understanding the Cost of Power Interruptions to U.S. Electricity Consumers*, Ernest Orlando Lawrence Berkeley National Laboratory, September 2004, e.g., Figure ES-1 among other discussions in the paper: http://certs.lbl.gov/pdf/55718.pdf (September 2010).

[6] *Accommodating High Levels of Variable Generation*, special report of the North American Electric Reliability Corporation, Princeton, New Jersey, April 2009, Executive Summary, http://www.nerc.com/files/IVGTF_Report_041609.pdf (August, 2010).

ENVIRONMENTAL PERFORMANCE

Politicians, environmental stakeholders and the general public are increasingly looking to the electricity sector to reduce the emissions resulting from power generation as well as to drive further emission reductions by replacing liquid fossil fuels in the transportation sector. The smart grid is expected to drive carbon emissions reductions by facilitating renewable power generation, enabling electric vehicles as replacements for conventional vehicles, reducing energy use by customers, and reducing energy losses within the grid. Each of these positive outcomes requires vital information to be available to the grid operators that has not traditionally been available; distribution automation furnishes these required tools.

OPERATIONAL EFFICIENCIES

The smart grid will be expensive to develop and deploy, but if implemented pragmatically should provide operational efficiencies that outweigh these costs. The electricity industry went through a growth phase in the 1970's and 1980's, and aging infrastructure is coming due for replacement. In fact, the electricity industry in Canada is expected to invest $11 billion in infrastructure replacement in each of the next 20 years just to replace existing assets. This is a cost that must be incurred with or without the automation of the grid. Rather than replacing assets with identical assets, however, the smart grid, if planned pragmatically, represents the technological upgrades that will pay a positive return on the investment over the deployed life cycle through energy demand reductions, savings in overall system and reserve margin costs, lower maintenance and servicing costs (e.g. reduced manual inspection of meters), and reduced grid losses, and new customer service offerings.

While some benefits to operational efficiency fit quite nicely into a business plan, such as line loss reduction or improved asset management, some elements rely on a societal assessment of worth, rather than an accountant's calculation of "value". For example, new subdivisions since the 1960s have been built with a preference for hiding distribution wires underground. While this practice provides tangible benefits that can be measured (i.e. extending the life of wires because they are not exposed to the elements), the business case is also supported by intangible benefits (i.e. the aesthetics value of not seeing the distribution system running through the neighbourhood).

This concept of tangible versus intangible operational efficiencies can also be illustrated through workplace safety, a topic that Canadian utilities take very seriously. This commitment to safe work environments is supported by several functionalities available through the smart grid, notably by reducing time on the road for meter reading, alerting workers of islanding, and allowing for some grid repairs to be performed remotely. Avoiding injuries certainly provides tangible operational benefits such as reducing lost time due to injury, but a portion of the benefit is attributed to the intangible health and safety benefits accrued to any worker whose job is made safer.

Operational improvements such as these are tough to quantify in a business case, but like undergrounding, once their worth is proven, rather than simply their "value", they are likely to become the new industry standard.

II. THE SMART GRID'S FIVE CAPABILITIES

The transition to a more automated grid—in pursuit of environmental, efficiency and resilience benefits—entails changes and enhancements across the grid value chain, from how the electricity supplier operates, to how the network is structured, to how the end user interacts with the grid infrastructure. These changes can be organized into five broad categories, and constitute the smart grid's key characteristics or "capabilities".

A) Demand Response

This capability refers to the capacity of the user or operator to adjust the demand for electricity at a given moment, using real-time data. Demand response can take the form of active customer behaviour in response to various signals, generally the price of electricity at the meter, or it can be automated through the integration of smart appliances and customer devices which respond to signals sent from the utility based on system stability and load parameters. For example, a residential hot water heater could be turned off by a utility experiencing high electricity loads on a hot day, or could be programmed by its owner to only turn on at off-peak times. Active demand management can help smooth load curves, which in turn can reduce the required reserve margins maintained by electricity generators. Some pilot projects can already claim results in this respect: the Olympic Peninsula Project, overseen by the Pacific Northwest National Laboratory on behalf of the US Department of Energy, dropped peak power usage by 15 percent. A similar project from Constellation Energy in Baltimore, Maryland, cut peak power demand by at least 22 percent—and as much as 37 percent. [7]

These capabilities have been rolled out in several Canadian jurisdictions to date; however the value of this technology depends on a number of factors. The first, of course, is customer take-up. If electricity customers do not sign up for voluntary utility load control programs or do not purchase the smart appliances and devices required, demand response programs will have little effect. Additionally, if the generating mix in a particular jurisdiction allows it to economically adapt to electricity demand, the value of demand response programs is diminished. In Alberta, for example, the average power divided by the peak power output, or "load factor", for the province is about 80%, which is quite high. As such, the value of peak shaving programs is diminished as compared to other Canadian jurisdictions with load factors below 80%.

It is important to note that demand response and energy conservation are not one and the same. Successful demand response smoothes out consumption levels over a 24-hour period, but does not encourage decreased consumption. Smart grid technologies that promote a reduction in the use of electricity include the Advanced Metering Infrastructure (AMI) and the Home Area Network (AM), both of which allow for increased customer control over their energy use.

B) Facilitation of Distributed Generation

As demand response is the management of system outputs, the facilitation of distributed generation is the management of system inputs. Some in the industry refer to the combined optimal management of both to be the "achievement of flow balance."

Traditionally, the grid has been a centralized system with one way electron flows from the generator, along transmission wires, to distribution wires, to end customers. One component of the smart grid allows for both movement and measurement in both directions, allowing small localized generators to push their unused locally generated power back to the grid and also to get accurately paid for it. The wind and the sun, however, generate energy according to their own schedule, not the needs of the system. The smart grid is meant to manage intermittency of renewable generation through advanced and localized monitoring, dispatch and storage.

In Ontario, the Energy Board has directed that it is the responsibility of the generator to mitigate any negative effects that connected supply may have

[7] David Biello, *The Start-Up Pains of a Smarter Electricity Grid*, Scientific American, May 10, 2010, http://www.scientificamerican.com/article.cfm?id=start-up-pains-of-smart-grid (September 2010).

on the distribution grid in terms of voltage variances and power quality. The optimal solution set to accomplish this, however, is still being examined.

In addition to intermittency challenges, distributed generation can cause instances of “islanding” in which sections of the grid are electrified even though electricity from the utility is not present. Islanding can be very dangerous for utility workers who may not know that certain wires have remained live during a power outage. Ideally, real time information will allow islanded customers to remain in service, while posing no risk to utility workers.

Again, the automation afforded by the smart grid offers a means to this end. When Louisiana was hit by Hurricane Gustav on September 1, 2008, an island was formed of about 225,000 customers who were disconnected from the main electricity grid. According to Entergy, the responsible utility, “synchrophasors installed on key buses within the Entergy system provided the information needed for the operators to keep the system operating reliably.”[8] This technology saved the utility an estimated $2-$3 million in restoration costs, and kept all customers in service (thereby avoiding economic losses to regional businesses).[9]

C) Facilitation of Electric Vehicles

The smart grid can enable other beneficial technologies as well. Most notably, it can support advanced loading and pricing schemes for fuelling electric vehicles (EVs). Advanced Metering Infrastructure would allow customers to recharge at off-peak hours based on expected prices and car use patterns, while bidirectional metering could create the option for selling back stored power during on-peak hours. Although significant EV penetration is still a medium to long-term projection, some cities and regions have started experiments and the existence of a smart grid is essential to their uptake.

This area of the smart grid provides an illustrative example of the potential risk to utilities of getting caught in the middle. Many policy makers and car manufacturers correctly point out that widespread charging infrastructure may help incent customers to switch to electric vehicles. While this is true, we must recognize that charging infrastructure alone may not be enough to change customer behaviour; until a breakthrough technology is discovered by the automotive industry, electric vehicles will still have relatively high price tags and limited range. As such, prudence dictates that utility investments in EV infrastructure ought to respond to the automotive purchasing patterns of their customers rather than laying the groundwork for a fuel switch that is still largely dependent on technological breakthroughs. If utilities invest in infrastructure now, and the EV market takes longer than promised to develop, customers may not feel well served.

D) Optimization of Asset Use

Monitoring throughout the full system has the potential to reduce energy losses, improve dispatch, enhance stability, and extend infrastructure lifespan. For example, monitoring enables timely maintenance, more efficient matching of supply and demand from economic, operational and environmental perspectives, and overload detection of transformers and conductors. Or as Miles Keogh, Director of Grants and Research at the National Association of Regulatory Utility Commissioners in the US, argues in a recent paper, system optimization can occur “through transformer and conductor overload detection, volt/var control, phase balancing, abnormal switch identification, and a host of ways to improve peak load management.” Thus, as he concludes, “while the smart meter may have become the ‘poster child’ for the smart grid, advanced sensors, synchro-phasors, and distribution automation systems are examples of equipment that are likely to be even more important in harnessing the value of smart grid.”[11]

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[8] Floyd Galvin and Chuck Wells, “Detecting and Managing the Electrical Island Created by Hurricane Gustav,” *Success Stories*, North American Synchrophasor Initiative, p. 1, http://www.naspi.org/stories/pilot_fundamental/entergy_hurricane_gustav.pdf, (July, 2010).

[9] Galvin and Wells, 2.

[10] Miles Keogh, “The Smart Grid: Frequently Asked Questions for State Commissions,” The National Association of Regulatory Utility Commissioners, May 2009. <http://www.naruc.org/Publications/NARUC%20Smart%20Grid%20Factsheet%205_09.pdf>. [confirm citation].

[11] Keogh, 4.

For example, smart grid monitoring helps utilities asses their line proximity issues as it relates to trees and tree growth, because dense growth results in a significant increase in the number of short voltage blips that occur. Early detection of these short line contacts by trees will assist utilities in their "just in time" tree programs, effectively focussing crews on the correct "problem areas".

In addition, network enhancements, and in particular improved visualization and monitoring, will enable "operators to observe the voltage and current waveforms of the bulk power system at very high levels of detail." This capability will in turn "provide deeper insight into the real-time stability of the power system, and the effects of generator dispatch and operation;" and thereby enable operators to "optimize individual generators, and groups of generators, to improve grid stability during conditions of high system stress."[12]

E) Problem Detection and Mitigation

Many utility customers do not realize the limited information currently available to grid operators, especially at the distribution level. When a blackout occurs, for example, customer calls are mapped to define the geographic area affected. This, in turn, allows utility engineers to determine which lines, transformers and switches are likely involved, and what they must do to restore service. It is not rare, in fact, for a utility customer care representative to ask a caller to step outside to visually survey the extent of the power loss in their neighbourhood. It is a testament to the high levels of reliability enjoyed by electric utility customers that most have never experienced this; however, it is also evidence of an antiquated system.

While SCADA and other energy management systems have long been used to monitor transmission systems, visibility into the distribution system has been limited. As the grid is increasingly asked to deliver the above four capabilities, however, dispatchers will require a real-time model of the distribution network capable of delivering three things: 1) *real-time monitoring* (of voltage, currents, critical infrastructure) and reaction (refining response to monitored events); 2) *anticipation* (or what some industry specialists call "fast look-ahead simulation"); and 3) *isolation* where failures do occur (to prevent cascades).

On any given day in the United States, roughly "500,000 U.S. customers are without power for two hours or more"[13] costing the American economy between $70 and $150 billion a year.[14] This significant impact on economic activity provides a strong incentive to develop the smart grid, which is expected to reduce small outages through improved problem detection and isolation, as well as storage integration. It is also

[12] *Methodological Approach for Estimating the Benefits and Costs of Smart Grid Demonstration Projects,* EPRI, January, 2010, p. 4–21 (July, 2010).

[13] Massoud Amin and Phillip F. Schewe, "Preventing Blackouts: Building a Smarter Power Grid," *Scientific American*, August 13, 2008, http://www.scientificamerican.com/article.cfm?id=preventing-blackouts-power-grid&page=3, (September, 2010)

[14] Scientific American says that "estimates peg the economic loss from all U.S. outages at $70 to $120 billion a year," while NARUC says "outages cost between $80 and $150 billion every year."

expected to reduce the likelihood of big blackouts, such as the infamous 2003 blackout that impacted most of the Eastern seaboard.

The 2003 blackout left more than 50 million people without power for up to two days, at an estimated cost of $6 billion, and contributed to at least 11 deaths.[15] A root cause analysis revealed that the crisis could not have begun in a more innocuous way: a power line hit some tree branches in northern Ohio. An alarm failed to sound in the local utility, other lines also brushed against trees, and before long there was a cascade effect—a domino of failures—across eight US states and one Canadian province.

With proper monitoring, now capable through smart grid innovations, some proponents believe that a cascading blackout mirroring that of 2003 should become so remote a possibility as to become almost inconceivable.[16] Intelligent monitoring on a smarter grid allows for early and localized detection of problems so that individual events can be isolated, and mitigating measures introduced, to minimize the impact on the rest of the system. The current system of supervisory control and data acquisition (SCADA), much of it developed decades ago, has done a reasonably good job of monitoring and response. But it has its limits: it does not sense or monitor enough of the grid; the process of coordination among utilities in the event of an emergency is extremely sluggish; and utilities often use incompatible control protocols—i.e. their protocols are not interoperable—with those of their neighbours.

If Ohio already had a smart grid in August 2003, history might have taken a different course.[17] To begin with, according to Massoud Amin and Phillip Schewe in a Scientific American article, "fault anticipators… would have detected abnormal signals and redirected the power… to isolate the disturbance several hours before the line would have failed."[18] Similarly, "look-ahead simulators would have identified the line as having a higher-than-normal probability of failure, and self-conscious software… would have run failure scenarios to determine the ideal corrective response." As a result, operators would have implemented corrective actions. And there would be further defences: "If the line somehow failed later anyway, the sensor network would have detected the voltage fluctuation and communicated it to processors at nearby substations. The processors would have rerouted power through other parts of the grid." In short: customers would have seen nothing more than "a brief flicker of the lights. Many would not have been aware of any problem at all."[19] Utility operators stress that the smart grid does not spell the end of power failures; under certain circumstances such as these, however, any mitigation could prove very valuable indeed.

A more reliable grid is also a safer grid. First, as discussed previously, smart grid technology allows for "anti-islanding" when needed. Detection technology can ensure that distributed generators detect islanding and immediately stop producing power. Second, power failures can leave vulnerable segments of the population, such as the sick or elderly, exposed to the elements or without power required by vital medical equipment. Third, safety is also enhanced through electricity theft reductions. As BC Hydro points out, "energy diversions pose a major safety risk to employees and the public through the threat of violence, fire and electrocution." [20]

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15 JR Minkel, "The 2003 Northeast Blackout – Five Years Later," *Scientific American*, August13, 2008, http://www.scientificamerican.com/article.cfm?id=2003-blackout-five-years-later, (August, 2010).

16 Amin and Schewe.

17 Amin and Schewe.

18 Amin and Schewe

19 BC Hydro, http://www.bchydro.com/planning_regulatory/projects/smart_metering_infrastructure_program/program_overview_and_status.html (October, 2010)

III. BUILDING BLOCKS

The five capabilities just reviewed—demand response, facilitation of distributed generation, facilitation of electric vehicles, optimization of asset use, and problem detection and mitigation—have excited considerable interest in policy discussions about the smart grid. To assess the merits of each, however, we ought to bear in mind that their value is derived from their ability to contribute towards the three ultimate objectives of increased resilience, improved environmental performance, and operational efficiencies. In other words, we need to consider their contribution in practical terms.

This question of practicality gives rise to a consideration of the building blocks needed to implement the various capabilities. Implementation of a smart grid will require investments and changes in tangible infrastructure complemented by investments and changes in soft infrastructure. A detailed understanding of the benefits and challenges for both of these categories is required when assessing the business case for the various capabilities of the smart grid.

A) Hard Infrastructure

Key investments and changes in tangible infrastructure to deliver smart grid capabilities are the following:

SMART METERS / ADVANCED METERING INFRASTRUCTURE (AMI)

Smart meters and the information backhaul systems required to support them are probably the best known, and also likely the most expensive, building block supporting a smart grid. As of September 30, 2009, electricity distributors in Ontario had installed approximately 2,883,000 residential and 171,000 general service (<50 kW) meters.[21] In the Ontario Energy Board's March 2010 audit of electricity distributors' smart meter regulatory accounting, they found capital expenditures for all meters to be about $633 million, and OM&A expenditures to be $63 million.[22]

Fully enabled smart meters can communicate in real-time between users and energy suppliers about energy use and prices, coordinate household consumption based on these signals and customer preferences, and facilitate measurement and customized pricing. AMI can also enable net-metering which allows for the flow of electricity onto the grid from residential or commercial distributed power generation.

The process of determining electricity usage and then billing accordingly has high transaction costs on a manual meter reading system, especially in regions that involve considerable driving distance from the utility to the meters, as in parts of Canada. A number of reports identify avoided meter reading costs as a major benefit of AMI. The Brattle Group, for instance, provides an illustrative theoretical example of a smart power region with one million residential customers, 100,000 small and medium commercial and industrial customers, and 5,000 large commercial and industrial customers. With annual meter O&M costs assumed to be $18 million per year, the present value of avoided meter reading costs, over a 20 year forecast horizon, amounts to $243 million.[23]

There is also empirical evidence. FortisAlberta has installed 466,000 meters and automated 171 substations across its primarily rural service area. Previously contracted meter readers drove more than six million kilometres annually; escalating fuel costs, coupled with rising labour costs, led to a $1.7 million increase in the cost of these meter reads from 2005 to 2006 alone. All utilities with an AMI deployment can expect substantial fuel and labour cost savings (along with associated CO_2 and worker safety benefits). Moreover, as the electricity meter is typically the only meter at a residential location with its own power supply (vs. battery power for natural

[21] *Sector Smart Meter Audit Review Report*, Ontario Energy Board Regulatory Audit and Accounting, March 31, 2010, http://www.oeb.gov.on.ca/OEB/_Documents/Audit/Smart_Meter_Audit_Review_Report.pdf, (July 2010).

[22] *Ibid*.

[23] Philip Q. Hanser and Ahmad Faruqui, "Wise Energy Use & Smart Grid Strategy," presentation by the Brattle Group, 2009, p. 8.

gas and water meters), it is best positioned to perform the energy intensive task of backhauling meter data and sending it to the respective utilities. This synergy can significantly bolster the AMI business case for each utility involved.

An additional benefit of AMI, less widely discussed, is that it will allow for real-time load measurement and management, which in turn could detect (and subsequently mitigate) instances of theft. As BC Hydro argues, additional load created by energy diversions contributes to premature transformer failures causing customer outages and increased costs to replace assets. The utility is therefore implementing new technologies and information analytics tools to identify premises where illegal diversions are occurring and reduce the impact on legitimate ratepayers. In the last three years, BC Hydro has shut down more than 1,500 electrical diversions, all of them associated with marijuana growing operations. Enhanced automation and monitoring will allow it to detect more such instances of theft, and faster. [24]

AMI challenges do, of course, exist. In the absence of interoperability and cyber-security standards, further issues may arise from the use of closed and proprietary systems that may be incompatible with common communication standards and protocols and other technologies (further discussed in the soft infrastructure section below).

Additionally, AMI is a system, much like the smart grid itself, on which applications are built. Smart meters allow for customer engagement in their electricity consumption; uptake on this offering, however, is critical to deriving the full value from this significant investment.

Particularly within this context of customer engagement, while smart meters have been identified as an important building block in support of overall system optimization, initial deployments have not been without challenges. We will examine lessons learned later in this paper.

NETWORK DEVICES AND ENHANCEMENTS

Grid enhancements will be required to integrate additional renewable and distributed generation into the grid. These enhancements will include enhancement of monitoring systems—more locations, with better visualisations and improved simulations, as well as improved data processing across the entire grid. They will also include advanced voltage control, increased fault detection, digitization, and (automatic) system protection practices. These improvements have the potential to limit losses, optimize integration of distributed resources and electric vehicles, and enhance the resilience of the system. The distribution grid in particular, as opposed to the already quite "smart" transmission system, could gain significantly from centralized optimization through remote monitoring and control. d optimization through remote monitoring and control.

The challenge faced by utilities is to integrate the various streams of operational data into coherent tools that will augment planning and other asset decisions, such as asset analytics and flow analyses. Many in the industry refer to this is the coming "data tsunami" and vendors are working hard to develop the software applications required to take tera- or even peta-bytes of data and produce concrete information to aid in utility decision making. However, while technologies are developing rapidly, it raises the possibility that what is now a state of the art system could become obsolete in a few years. This concern has caused at least one major Canadian utility to recently re-examine its timelines for rolling out a comprehensive Demand Management System.

[24] "Electricity Theft" BC Hydro, http://www.bchydro.com/safety/marijuana_grow_ops.html, (August, 2010).

DISTRIBUTED ENERGY STORAGE

Distributed energy storage has the potential to optimize the stability of the power supply resulting in reduced grid losses, reduced power outages and improved power quality. Local storage will also enable increased penetration of renewable resources and ensure their integration will not reduce the stability and reliability of energy supply. The main obstacle for employing additional flexible storage solutions such as batteries, or pumped storage, is their relatively high cost. Plug-in electric vehicles could provide distributed storage, but significant penetration is still many years out and it is not yet clear how substantial the storage contribution from electric vehicles will prove to be.

HOUSEHOLD APPLIANCES

To get the full value from the smart grid, customers will require appliances to communicate with a home area network (HAN) that will optimize electricity use depending on market signals (and within limits set by the customers). The magnitude of the replacements or retrofits required—a change that will be dispersed across millions of households—poses some clear challenges at the interplay of technology, standardization among suppliers, and customer behaviour.

B) Soft Infrastructure

Soft infrastructure required includes the following issues:

INTEROPERABLE COMMUNICATION STANDARDS AND PROTOCOLS

One of the lessons of the 2003 blackout, according to Arshad Mansoor, a smart grid expert at the Electric Power Research Institute in California, is that "you can't just look at your system. You've got to look at how your system affects your neighbours and vice versa."[25] Since that time, and as smart grid discussions have advanced, a strong consensus has emerged that the smart grid must have robust protocols and standards to ensure interoperability of smart grid devices and systems. The National Institute of Standards and Technology (NIST), the federal entity tasked with developing smart grid standards in the US context, provides four good arguments for them. First, without standards, there is a risk that "the diverse smart grid technologies that are the objects of these mounting investments will become prematurely obsolete;" second, and worse, they could "be implemented without adequate security measures."[26] To elaborate on the security point, if the technology is proprietary and only well understood by its proponents, it could contain vulnerabilities to hackers or even terrorists.

Third, a "[l]ack of standards may also impede future innovation and the realization of promising applications;" and fourth, on a related note, "standards enable economies of scale and scope that help to create competitive markets."[27] A lack of standards may encourage monopolistic and rent-seeking behaviour.

There is also a fifth argument: protection of customer privacy. This issue does not receive enough attention—it has been called the "sleeper issue" of the smart grid—but is now being addressed, for instance, by the Privacy Commissioner of Ontario, who has proposed a set of principles to support smart grid development.[28]

As NIST notes, whereas the U.S. smart grid market will double between 2009 and 2014, "to nearly $43 billion," over the same time frame "the global market is projected to grow to more than $171 billion, an increase of almost 150 percent."[29] Ideally, therefore, such standards will be global in scope.

In Canada, many smart grid stakeholders have identified electricity system standardization issues and activities as a high priority. They are voicing Canadian perspectives through both American NIST Smart Grid Interoperability Panel activities as well as internationally oriented IEC efforts. The

[25] JR Minkel, "The 2003 Northeast Blackout – Five Years Later," *Scientific American*, August 13, 2008, <http://www.scientificamerican.com/article.cfm?id=2003-blackout-five-years-later&page=2>.

[26] *NIST Framework and Roadmap for Smart Grid Interoperability Standards*, Release 1.0, Office of the National Coordinator for Smart Grid Interoperability, National Institute of Standards and Technology, U.S. Department of Commerce, NIST Special Publication 1108, January, 2010, p. 14.

[27] NIST, 14.

[28] *Smart Privacy for the Smart Grid: Embedding Privacy into the Design of Electricity Conservation*, PbD, Information and Privacy Commissioner, Toronto, Ontario, November 2009, p. 3, http://www.ipc.on.ca/images/resources/pbd-smartpriv-smartgrid.pdf (July, 2010).

[29] NIST, 14.

key challenge will be to identify, and help resolve, discrepancies between NIST and IEC standards development. As operators within the North American power grid that reply on global supply chains for technological solutions and equipment, Canadian utilities must remain keenly focused on this challenge.

Additionally, Canada's Federal Government must recognize the benefit of standards to the broader public interest, namely lowering the cost and risk associated with smart grid deployment, by funding the Standards Council of Canada's work in this important area.

CYBER SECURITY STANDARDS

As previously noted in this paper, the addition of communications capabilities to the grid network creates countless additional points of entry into both the utility billing systems and the grid control systems. Cyber security standards are being developed at both the NIST and the IEC levels, but protocols will need to be continually re-assessed and updated.

There are two ways to think about this issue. The first is that there are now millions of new hackable points on the electricity grid network. Power supplies might be shut off to critical services such as first responders or hospitals; voltage control devices could be altered, frying equipment and devices attached to the network; and co-ordinated attacks could take an entire city offline. It is important to recognize that most power outages today are caused by damage to power lines and poles—equipment that is abundant and easy to quickly replace. An attack that requires systematic diagnostic testing and the replacement of equipment that is generally built to order could take weeks or even months.

That is the worst case. The second way to look at the issue is to look to the other industries for which cyber security is critical—banking, wireless communications, government networks, etc. While each of these sectors must remain vigilant of their systems, and attacks do regularly occur, containment protocols have been developed to ensure that hacking attempts can be isolated and dealt with. Canadian electric utilities are working with vendors and standards bodies to ensure that it is this second vision that will play out.

Even with this pragmatic approach, utilities will have to determine what actions are appropriate for customers who have attempted to breach security protocols (or have been unwittingly used as a conduit by hackers)—can the utility cut them off from service? At what point should be police become involved? These questions do not yet have definitive answers, but the issues are clearly looming.

1.8 GHZ SPECTRUM

The Canadian utility industry was recently awarded a dedicated slice of radio spectrum for various applications including high speed teleprotection, supervisory control and data acquisition (SCADA), telemetry and mobile radio, and smart grid development.

The electricity sector continues to emphasize to Industry Canada the critical infrastructure nature of the industry and the need to protect and enhance existing spectrum resources as well as ensure access to necessary bandwidth at a reasonable cost and without having to compete with nonessential and/or commercial services. Utility developers worldwide are asking for a similar allocation and regulatory treatment, including in Australia and the United States.

CUSTOMER ENGAGEMENT

There is a general lack of public awareness of the smart grid, and a lot of confusion in sorting through the various claims and definitions that are being advanced to explain it. It will be important for customers to have a much better understanding

of the benefits of smart grids if they are to be introduced effectively and sustainably. Since the high cost of smart grid implementation will, directly or indirectly, be shared by customers, if they are not convinced by claims regarding current and future benefits, they are likely to resist and challenge those costs over time.

In addition, as Canada emerges from the recent economic crisis, customers are especially sensitive to the cost of electricity. This statement is supported by CEA customer attitudes research, which reveals that the most significant driver of customer dissatisfaction is price, which in turn reinforces the importance of renewed consumer dialogue and education in advance of a capital-intensive project like the smart grid.[30]

Customers must be made aware that the grid infrastructure is aging and needs to be replaced, and is concurrently being upgraded to take advantage of the latest technologies. Utilities, vendors and policy-makers must deliver on the promised functionality without expecting an immediate reorienting of the typical electric utility customer from passive market participant to active energy manager.

CHANGES IN CUSTOMER BEHAVIOUR

Complicating this need for customer buy-in is the fact that the value of the smart grid system is intrinsically tied to their willingness to use the tools made available to them to manage their electricity use.

It is important to note that households *already* have an array of options for reducing energy use and saving money that go untapped (e.g., isolation of heating and cooling, better insulation, lighting changes). Thus history shows that even where energy savings have a short-term financial pay-off, it may not be enough to convince the customer to act. Customer education will likely need to be combined with regulatory incentives and disincentives before full participation can be realized.

STAKEHOLDER AGREEMENT AND COORDINATION

The coordination challenges involved in deploying a smart grid to its full potential is daunting: to be done properly it will have to involve governments, regulators, electricity generators (both centralized and distributed), transmitters, distributors, equipment and service providers, final customers, and neighbouring jurisdictions. But the challenge is more than just finding agreement and coordinating steps forward.

Many of the issues that involve coordination will involve changes to the industry's traditional business model. There will be new entrants, new forms of interaction, and new areas of uncertainty and overlapping

[30] Drawn from the results of two decades of CEA customer polling.

accountabilities that will have to be resolved. Issues for coordination, agreement, and change management will include, at a high level: a shared understanding of the benefits and risks involved in implementing a smart grid; the speed of and order of the roll-out; cost/benefit sharing mechanisms among private sector participants, and between the public and private sectors; and technological standards.

C) Summary Map of Building Blocks

The table below illustrates conceptually the strongest relationships between the various infrastructure requirements or building blocks and the various smart grid capabilities. In other words, there could be relationships other than those identified but these are meant to focus attention on the most important.

		Smart grid capabilities				
		Demand Response	Facilitation of Distributed Generation	Facilitation of Electric Vehicles	Optimization of Asset Use	Problem Detection & Mitigation
Hard infrastructure requirement	Smart Meters / Advanced metering infrastructure (AMI)	Necessary	Necessary	Necessary		Supporting
	Transmission and Distribution Enhancements	Supporting	Necessary	Necessary	Necessary	Necessary
	Distributed energy storage	Supporting	Necessary	Supporting	Supporting	Supporting
	Household appliances communication	Supporting				
Soft infrastructure requirement	Standards for communication	Necessary		Necessary		Supporting
	Customer education	Necessary	Necessary	Necessary	Supporting	Supporting
	Customer behavioural adjustments	Necessary	Supporting	Supporting		
	Stakeholder agreement and communication	Necessary	Necessary	Necessary	Necessary	Necessary

● = Necessay requirement ● = Supporting requirement

IV. GROWING PAINS AND LESSONS LEARNED

As illustrated in this paper, the smart grid offers a number of proven and potential benefits. But it still has some ways to go in demonstrating its full value and in addressing implementation challenges. A survey of international smart grid reports, media articles and discussions with experts yields a number of growing pains—early difficulties and challenges—for the smart grid. Key difficulties can be grouped into the following categories: security, privacy, the cost of pilot projects and stakeholder engagement.

SECURITY

- **Worries about Vulnerability to Sabotage.** The smart grid means more information technology, and some observers worry that it will be vulnerable to sabotage. A CNN article in 2009 cited tests showing that "a hacker can break into the system, and cybersecurity experts said a massive blackout could result."[31] A security firm, IOACtive, found that a hacker, with only $500 in equipment and a limited electronics and engineering background could "take command and control of the [advanced meter infrastructure] allowing for the en masse manipulation of service to homes and businesses."[32] Commenting on the controversy, William Sanders, principal investigator for the National Science Foundation Cyber Trust Center on Trustworthy Cyber Infrastructure for the Power Grid, responds: "I don't think the sky is falling. I don't think we should stop deployment until we have it all worked out. But we have to be vigilant and address security issues in the smart grid early on."[33]

  A number of observers point to two steps that could mitigate these security risks: first, industry standards; second, "an open platform, which will allow developers to be able to contribute their best solutions."[34]

PRIVACY

- **Worries about Invasions of Privacy.** A number of smart grid experts believe the risk of potential privacy violations has not received adequate attention. As Ann Cavoukian, Ontario's Information and Privacy Commissioner, sums up the concern, the smart grid "introduces the possibility of collecting detailed information on individual energy consumption use and patterns within the most private of places—our homes. We must take great care not to sacrifice consumer privacy... Information proliferation, lax controls and insufficient oversight of this information could lead to unprecedented invasions of consumer privacy."[35] As mentioned earlier, this issue needs to be addressed with clear standards and strict oversight.

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[31] Jeanne Meserve, "'Smart grid' may be vulnerable to hackers," CNN.com, March 21, 2009, <http://edition.cnn.com/2009/TECH/03/20/smartgrid.vulnerability/?iref=mpstoryview>, (September, 2010).

[32] Meserve.

[33] Meserve.

[34] See e.g. Katie Fehrenbacher, "Securing the Smart Power Grid from Hackers," *Bloomberg Business Week*, March 23, 2009, http://www.businessweek.com/technology/content/mar2009/tc20090320_788163.htm, (August, 2010).

[35] *Smart Privacy for the Smart Grid: Embedding Privacy into the Design of Electricity Conservation*, PbD, Information and Privacy Commissioner, Toronto, Ontario, November 2009, p. 3, http://www.ipc.on.ca/images/resources/pbd-smartpriv-smartgrid.pdf (July, 2010).

PILOT PROJECT COSTS

» **Criticism of Cost of Boulder's Smart Grid Initiative.** The smart grid city initiative in Boulder, Colorado, has cost Xcel and its partners $100 million, or $2,000 per customer. Mike Carlson, the now-former chief information officer at Xcel Energy in Minneapolis, Minn., which is running the "smart grid city", said quite bluntly that "it is unsustainable and nondeployable at that cost." He further noted that cost would have to drop to $500 per customer to be viable. "We know these things will be effective in delivering something. The question is: will they justify their cost? "[36]

As a pilot program, the Boulder Smart Grid Initiative was a first mover on many of the technologies deployed, and certainly paid a premium on per-unit and per-household costs to do so. That is to be expected. The real lesson from Boulder is that the high costs of pilot programs are best alleviated by democratizing both the cost burdens and the lessons learned; in Canada, the Federal government has proven successful at mitigating the jurisdictional costs of pilot programs, while industry associations such as CEA play a vital role in disseminating industry best practices.

STAKEHOLDER ENGAGEMENT

» **Regulator Cites Obsolescence (and more) in Rejecting Smart Meter Proposal.** In June 2010 the Maryland Public Service Commission (PSC) rejected Baltimore Gas and Electric's initial proposal to deploy smart meters. The fear of technological obsolescence had an impact on the outcome; in its decision, PSC noted that "All the federal funding in the world would not have made Sony's Betamax a wise investment, for example… Those who invest in new technology as it becomes available often find themselves re-investing much sooner than they anticipated."[37] It was not, however, only technological concerns that derailed BG&E's submission. PSC encouraged the utility to re-file, but to pay special attention to three areas: modify the cost recovery mechanism to incorporate some form of shareholder risk; eliminate the mandatory time-of-use rate mechanism; and include a specific customer education plan. The PSC approved BG&E's refilling that took into consideration these recommendations.

Technologies are maturing, and interoperability standards are under development, abating to a degree the fear of obsolescence. The latter three concerns, however, are increasingly being cited by utility regulators, and can be summarized as: risk/return balance, new mandatory services for customers and non-technological elements of deployment programs. The lessons learned by BG&E allow Canadian utilities to better address these latter three recommendations when designing and proposing smart grid deployment programs.

» **Class-Action Lawsuit Against Pacific Gas & Electric.** In Bakersfield, California, in what has been called a "PR nightmare," PG&E is being sued by thousands of residents seeking damages from the utility and third parties involved in its 6.7 million meter, $2.2 billion rollout. The residents claim "their new smart meters are malfunctioning because their bills are much higher than before." PG&E, meanwhile, "claims higher bills are due to rate hikes, an unusually warm summer, and customers not shifting demand to off-peak times when rates are lower."[38] The accuracy of the meters has since been verified by an independent study, vindicating PG&E legally; however, as one observer comments, "It seems that PG&E's rollout is woefully under resourced at the back-end… Transparency and communications failures can lead to utilities being sued by their customers… The PR fallout from the Bakersfield rollout… may potentially set back smart grid projects in California for years."[39]

The customer is always right—even when they are wrong (in this case, about the poor accuracy

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[35] *Smart Privacy for the Smart Grid: Embedding Privacy into the Design of Electricity Conservation*, PbD, Information and Privacy Commissioner, Toronto, Ontario, November 2009, p. 3, http://www.ipc.on.ca/images/resources/pbd-smartpriv-smartgrid.pdf (July, 2010).

[36] David Biello, *The Start-Up Pains of a Smarter Electricity Grid*, Scientific American, May 10, 2010, http://www.scientificamerican.com/article.cfm?id=start-up-pains-of-smart-grid (September 2010).

[37] Order No. 83410, Maryland Public Service Commission, June 21, 2010, pg. 40, http://webapp.psc.state.md.us/Intranet/sitesearch/whats_new/Order%2083410_BGE%20AMI%20Application_CN%209208.pdf (September, 2010).

[38] "PG&E smart meter problem a PR nightmare," November 21, 2009, http://www.smartmeters.com/the-news/690-pgae-smart-meter-problem-a-pr-nightmare.html, (July, 2010)

of the meters). PG&E has provided stakeholders with perhaps the most important lesson to date, and Canadian utilities have taken the message to heart. In mid-September in Ontario, the conversation moved in a similar direction to California, with such media as the Financial Post ("*Are You Frying Your Eggs at 4a.m. Yet*") and the Globe and Mail ("*Ontario's Hydro's Smart Meters Give Dumb Results: Critics*") airing the complaints of a segment of outspoken customers. As Ontario utilities continue their engagement campaigns in step with the provincially mandated AMI roll-out schedule, the customer concerns seem to be easing. It has, however, certainly underscored for all Canadian utilities the need to put the customer first when in any way altering the service delivery model that customers have, in almost all cases, grown up with—cheap, reliable electricity with minimal participation required.

» **Consumer Groups Criticize Southern California Edison's AMI Program.** The theme of customer engagement can be expanded to other stakeholders in the regulatory process, whether they are, for example, consumer groups, NGOs, industry associations, or aboriginal representatives. When Southern California Edison introduced an AMI program, and despite the California Public Utility Commission's "conclusion on the positive benefits," some leading consumer groups in California were "unconvinced."[40] The PUC decided to approve the program despite the opposition, and the utility has since had to work very hard at communicating benefits to its customers, generally using a customer by customer approach. It is an instructive case because it shows that it is not enough to obtain support from the regulator—stakeholder engagement at the consultative stages are also important.

A clear message that has emerged in Canada is that there is no shortage of stakeholders who feel that the smart grid will have at least some impact (generally positive) on the mandate they have been asked to deliver by those they represent. For example, the Alberta Utilities Commission has been directed to review how smart grid technology, such as advanced metering or smart metering infrastructure, can be used to modernize the electricity system in Alberta.[41] Procedural submissions were accepted throughout much of the summer, and the varied list of stakeholders is indicative of the smart grid's potentially broad applicability and impact. Registered parties include, among the utilities and many others: the Pembina Institute, Citizens Advocating for the Use of Sustainable Energy, the City of Lethbridge, the City of Red Deer, GE Canada, Honeywell and Telus.

Electric utilities provide a vital "enabling service" for many other groups and industries. Canadian utilities have long understood this, and indeed pragmatism is ingrained in the industry's careful approach to change. The lesson learned through the AUC process and others, however, is that as the smart grid evolves, utilities must continually scan their business environment for emerging stakeholders (i.e. the automotive sector), and interface accordingly.

Some of these difficulties concern matters of perception, and are not insoluble. But matters of perception—especially at this early stage of smart grid deployment—are no less significant for electric utilities, because they go to the very credibility of the smart grid effort. Customer and stakeholder support will be essential for sustainable deployment. These lessons learned underscore the criticality of advocates, including both utilities and outside stakeholders, being able to explain and eventually prove the benefits of each component of the smart grid to the customers who purchase the service.

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39 Tom Raftery, "PG&E smart meter communication failure – lessons for the rest of us," Green Monk blog, December 16, 2009, http://greenmonk.net/pge-smart-meter-communication-failure/, (June, 2010)

40 Comments by Fred Butler, President of NARUC, as quoted by James Bradford Ramsay, *"Implementation of Smart Grid Technology,"* Initial Comments of the National Association of Regulatory Utility Commissioners in Response to NPB Public Notice #2, Before the Federal Communications Commission, October 2, 2009, DA 09-2017, http://www.naruc.org/Testimony/09%201002%20NARUC%20Smart%20Grid%20comments.fin.pdf.

41 "Special Inquiries", Alberta Utilities Commission: http://www.auc.ab.ca/items-of-interest/special-inquiries/Pages/default.aspx

V. AN OPTIMAL PATH FORWARD

The smart grid is many things, but one thing it is not is a technological mystery. The key capabilities are fairly well understood, as are the building blocks, although new technologies will emerge and existing technologies will continue to mature. What remains somewhat unclear is to what extent the suite of technologies will ultimately deliver value to the end customer, and how this value is best communicated. In order to provide clarity on these issues, all stakeholders must work together, including vendors, governments, regulators and utilities. We are at a cross-roads with respect to customer buy-in and it is incumbent on all parties to introspectively examine how best to proceed.

VENDORS

After the last major electric utility infrastructure build-out of the early 1980s, most utilities in Canada shed their R&D arms in an effort to reduce costs. This arrangement has mostly served its purpose, with the utility industry reliant on partnerships with external technological developers to meet its needs. This has become especially acute with the advent of the smart grid, and again the utilities by-and-large feel well served.

However, the smart grid has brought about the need for another area of collaboration, this one less technological in nature, around managing expectations of what the electricity grid is capable of. It is here that the two groups who best understand the technologies involved need to be on the same page, but it is also here that some discordant messaging has emerged. It is certainly an exciting and promising time for the industry, but recent customer and regulator push-back has underlined the need to stick with the age old adage of "under-promise and over-deliver."

GOVERNMENTS

Just as with the vendor community, policy-makers across Canada and the United States have been learning to be wary of hyperbole and treat the smart grid as they would any other pragmatic, incremental upgrade to the electricity system. This is not to say that elected officials should not tout the benefits of these improvements, only that they must work closely with the utilities within their jurisdictions to understand the pace and scope of the roll-outs.

Furthermore, it is important to note that many of the environmental performance benefits that the smart grid will deliver are benefits not restricted to one geographic area and as such rate payers may end up shouldering different levels of cost for the public good. For example, efforts in one service territory to integrate increased levels of non-emitting power supplies (i.e. wind and solar) may raise rates for some while assisting all Canadians towards our shared goal of reducing green house gas emissions by 17% by 2020. Federally funded pilot programs help to spread the burden of technological and operational development more equitably; moreover, this approach allows the industry as a whole to learn from the initiatives of their peers thus reducing the overall cost of development. For these reasons of equitability and efficiency, the federal government should initiate a second round of pilot programs under Natural Resources Canada. Similarly, the federal government should increase its financial support for the development of smart grid interoperability standards that serve all Canadians and provide the base on which to build our digital economy.

REGULATORS

The Smart Grid is certainly on the radar screen of every provincial electric utility regulator in Canada, and as is appropriate, each sees the smart grid through the lens of the jurisdiction over which they regulate.

Miles Keogh, Director of Grants & Research Development at the National Association of Regulatory Utility Commissioners, breaks down the smart grid from a regulatory perspective that is well supported by this paper. The smart grid, he says, can be broken down into direct value and option value. Direct value "represents the quantifiable value of components that, when introduced, will immediately improve the efficiency of the system and create cost-benefits such as distribution optimization and visualization. Benefits begin to accrue upon deployment rather than waiting for customer behaviour or further component deployment." Option value, on the other hand, refers to applications that "rely on additional activities before their value can be fully realized. In certain cases, like demand response enabled by smart prices and smart meters, realizing the value depends on customers changing their behaviour including responding to price signals. For other applications, such as distributed generation and PHEVs, customers must purchase, install, and utilize them before their value can fully be realized.

The addition of smart grid components creates the option for these technologies and activities to be deployed. This "option value," while not directly quantifiable, is nonetheless measurable and should be considered along with "direct value" components as applications for smart grid warrant."[42]

UTILITIES

Technologically, Canadian utility operators are in the best position to determine the scope and the pace of smart grid deployment in Canada. With respect to scope, they must consider the myriad of factors that vary strongly by region, including existing infrastructure and current grid characteristics, power supply mix (i.e. Quebec's hydropower resources vs. Alberta's use of fossil fuels), the distances connecting generation, wires and load, and even weather patterns. Business cases must be based on pragmatism operational experience, and customer buy-in, not the latest technological capability. As such, the Canadian utility industry has developed a list of key principles that will guide the deployment of the smart grid in Canada:

1. The relationship between the customer and the utility is paramount. The smart grid should be rolled out at a pace and at a scope to allow for this relationship to evolve and strengthen.
2. The existing grid has for many years delivered high quality low-cost electricity. Customers expect this and the rationale for rate increases will have to be communicated clearly.
3. Smart grid implementation should not pose any risk to reliability and quality of electricity service.
4. Smart grid investments should be rooted in a business case that identifies and quantifies the potential for sustainable value delivery, and is informed to the extent possible by experience elsewhere. This prudent approach can be achieved in part through R&D, pilots and demonstration projects, in partnership with the Federal government.
5. The optimal design and roll-out should be linked to local variables including current and intended generation mix, customer base, geographic profile, and other factors. Utilities themselves are in the best position to assess the impact of these variables on their service territory, and must consider them accordingly.
6. Cyber security must be taken seriously and customer privacy is of utmost importance.
7. Smart grid policies and standards should promote a flexible, non-proprietary, open infrastructure that is upgradable to avoid excess costs as a result of obsolescence.
8. Smart grid implementation requires careful attention to soft infrastructure, including forms of coordination and customer education, as much as it requires attention to hard infrastructure.
9. All stakeholders should be properly consulted before major smart grid investment decisions are made.

[48] Keogh, 5.

CONCLUSION

As we have seen, the smart grid is facilitating significant changes to the process of producing, transmitting and consuming electricity. Technological building blocks are allowing for new grid capabilities that, in turn, better support the utility mandate that increasingly includes certain societal benefits such as environmental performance and customer control. Early adopters have faced hurdles, but clear lessons have emerged that will assist all stakeholders as they carry out their respective roles.

The challenge, then, is to engage in a process of grid renewal that, through pragmatism and realistic expectations, can move beyond short term volatility to long term stability—and do it as quickly as possible with the greatest extent of stakeholder buy-in. In other words, to move beyond "high expectations" and the "valley of despair" and onto "continuous, incremental improvement" by confronting reality, crafting a vision, and communicating a belief in the process.

CONFRONTING REALITY

This paper strives to present an accurate and current "state-of-play" for the smart grid in Canada, drawing on the reality of the smart grid as seen through the eyes of utility operators and utility customers. While the operators understand the technologies, utility customers experience the end result, either good (i.e. a plug-and-play roof top solar array) or bad (i.e. rising electricity prices). As such, we must closely monitor both viewpoints closely.

The CEA conducts an annual Customer Attitudes Survey that tracks the Canadian electric utility customer experience across Canada. This information, as well as best practices discussed at meetings of the CEA Customer Council, provides a basis for understanding the smart grid "reality" as seen by customers. In addition, the CEA Distribution Council and Transmission Council both work to confront the smart grid reality as seen by utility operators. Together, this work can contribute to the development and maintenance of an accurate and realistic understanding of the smart grid that evolves along-side technologies and customer perceptions.

CRAFTING A VISION

The establishment of this generally accepted state-of-play understanding will provide the base upon which the Canada-specific smart grid vision can be built.

This will require the input from an even more diverse stakeholder group than that of the Alberta Utilities Commission process, and will not be easy to accomplish. Indeed, for any progress to be made, each stakeholder will need to continually confront reality and re-orient their positions to the reality of technological constraints and customer preferences.

It is also important to note that the Canadian smart grid will not be developed or deployed in a vacuum. The United States, Europe, much of Asia, Australia and New Zealand are all moving forward with smart grid innovation and messaging. Monitoring and engaging those conversations will be vital to ensuring that the Canadian smart grid vision is congruent to those of other jurisdictions.

COMMUNICATING BELIEF IN THE PROCESS

Finally, it is critical for the industry and stakeholders to maintain faith in the vision that emerges, even as aspects of the smart grid work their way through the change curve presented earlier in the paper. If the state-of-play is regularly and pragmatically assessed, and the vision is allowed to evolve and adapt over time, each stakeholder can be confident that the smart grid is being developed with the best information available. High expectations will become reasonable expectations, the valley of despair will become the flat plains of transition, and a state of continuous improvement will be achieved much more rapidly.

With the publication of this document, Canadian utilities signal our commitment to this process. We hope you will participate as well.

SOURCES

Research for this paper included some private discussions and inputs. In addition, we consulted a range of articles, papers, presentations and reports, including the following:

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"Annual Service Continuity Report on Distribution System Performance in Electrical Utilities," Electric Power System Reliability Assessment, 2009 Composite Version, Canadian Electricity Association.

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