IBM's Smarter Cities Challenge

Boulder

Report

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1. Executive summary

Introduction

The City of Boulder is one of 24 cities to earn a grant from IBM in 2011 as part of IBM's philanthropic efforts to build a Smarter Planet™. IBM's Smarter Cities™ Challenge aims to contribute to the improvement of high-potential cities around the world.

During a three-week period in May 2011, a team of six IBM executives worked in the City of Boulder to develop and deliver their recommendations on smart grid to City Manager Jane S. Brautigam and a wide range of stakeholders.

The Opportunity

The City of Boulder has established itself as a leader in environmentally responsible growth. In 2007 Xcel Energy, in partnership with the City, launched the SmartGridCity (SGC) project in Boulder. SGC involved "enhancements of the Xcel Energy's distribution system to employ various 'smart grid' technologies".

This first-of-its kind effort was supported by a range of partners, piloting new hardware, software and processes. The program was widely publicized, with the citizenship of Boulder expecting significant end-user benefits. As a trail-blazing project, the effort met various challenges that resulted in reduced scope and revised end results.

The City asked IBM to apply its expertise with smart grid technologies, smart grid deployments and energy efficiency to the SGC project. The City intends to leverage SGC capabilities to achieve aggressive energy objectives and continue its leadership in environmental and energy arenas.

The Scope

The team was tasked to answer three questions for the City of Boulder:

- What are SCG technical capabilities and their value to Boulder?
- What are the gaps in those capabilities that inhibit SGC from supporting the City's energy goals?
- What are IBM's recommendations on the capabilities to grow and expand SGC in line with the City of Boulder's focus on energy and its Climate Action Plan (CAP)?

Understanding

The team's first priority was to develop a thorough understanding of the requirements and priorities of the City of Boulder and its constituents. Boulder's Climate Action Plan (CAP) documents four key goals: providing stable and competitive rates; ensuring reliability; increasing renewable contribution and improving energy efficiency.

The team then held interviews with a broad cross-section of local constituents in order to understand the different perspectives and drivers within Boulder. These included City of Boulder staff and the City Council, large corporations, small and medium businesses, local community groups, environmental activists, State of Colorado government officials, US Department of Energy Laboratories and the University of Colorado. The team saw differences in each group's priorities in relation to the CAP. The business community focused on ensuring reliable energy with pricing stability, while local consumers looked to increasing renewable energy and exercising greater local control of their energy usage. Reconciling these differing views is of particular importance, as the majority of Boulder's energy consumption originates from large corporate consumers.

The team also had several interviews with Xcel Energy to fully understand the functionality and benefits of what was installed. In addition, the team accessed extensive technical and business documentation regarding the SGC project, reviewed other smart grid implementations and engaged experts from the private and public sector to evaluate the latest trends in functionality and benefits for smart grid infrastructure.

Our Assessment

Current SGC infrastructure provides significant value to Boulder. The deployment of a high-bandwidth communication medium, thousands of sensors, smart transformers, and smarter meters has transformed Boulder's electrical grid. SGC allows for effective 2-way communications, sensing and monitoring performance, remote control and automation and 24-hour delay reporting. To consume and utilize the exponential increase in data that SGC produces, Xcel Energy has also had to transform its grid operations, back office infrastructure and applications.

These enhancements to the electrical grid infrastructure provide significant value, improving transmission and distribution reliability and stability. These advances can also reduce utility operating costs.

However, the SGC project has yet to provide direct, visible customer value. When the project was initiated, SGC was advertised as providing customers with significant benefits including in-home real-time information access. This is now being piloted on a limited basis. This mismatch in expectations has been a source of friction between the utility, the City and its citizens.

SGC currently provides an enabling infrastructure that requires supplemental functionality, coupled with policy and behavioral changes to support transformative customer benefits. Based upon Boulder's CAP objectives and an evaluation of other smart grid implementations, the team identified ten key gaps in SGC functionality that are inhibiting valuable customer-facing initiatives. These include providing customers with near real-time usage information, demand forecasting and aggregation to enable local renewable sourcing, and interoperability between the grid and home devices.

Given the technical, social, and regulatory complexity of these gaps, it would be unwise to attempt to address them all simultaneously. To identify where to prioritize investments, we assessed both the impact of these gaps on the City's energy goals and the degree of difficulty and length of time to implement and deliver value.

Recommendations

The City of Boulder has a unique opportunity to collaborate. Smart grid deployments are iterative and therefore additional utility and customer value should be extracted as new technology and business models are introduced. These efforts can extend SGC benefits to the customer. Current SGC functionality provides a robust foundation to deliver high-impact projects.

We recommend that the City pursue a small number of funded pilot projects that are aligned to its CAP. Other standards-focused institutions in the area, including the National Renewable Energy Laboratory (NREL) and the National Institute for Standards in Technology (NIST) provide invaluable expertise and resources to accelerate any projects the City chooses to focus on. Some examples are below:

- Local renewable sourcing – developing aggregation to facilitate local renewable sourcing, investigate energy storage, develop a Renewable Energy Portfolio, and develop innovative renewable incentives;
- Solar & Plug-in hybrid electric vehicle (SPHEV) – extending SGC analytics and forecasting capabilities to enable and increase penetration of distributed generation and PHEVs;
- Green infrastructure management – improving energy efficiency in large building stock;
- Energy Efficiency for Small and Medium Businesses (SMBs) – SMBs currently receive minimal direct support in energy conservation through education and incentive programs. A targeted effort, leveraging SGC capabilities and analog efficiency improvements may provide significant value.

Conclusions

- We believe SGC provides significant value to Boulder. While the utility is experiencing the greatest proportion of benefits today, the measurable value to Boulder constituents should increase over time.
- SGC provides an infrastructure upon which valuable customer-facing initiatives can be built.
- These initiatives will require technical, behavioral and policy changes as well as the participation of multiple organizations to implement.
- The City of Boulder, in partnership with Xcel Energy, policy organizations, and local energy innovators should select targeted pilots that extend SGC functionality and support their energy objectives.

2. Introduction

A. IBM's Vision for Smarter Cities

By 2050, cities will be home to more than half the world's population, will wield more economic power and have access to more advanced technological capabilities than ever before.

Simultaneously, cities will struggle with a wide range of challenges and threats to sustainability in those core support and governance systems – transport, water, energy, communications, healthcare and social services. These governance issues are not however unique to cities. All over the globe, federal, state and local governments as well as private sector companies are looking at innovative ways to reduce the problems of siloed and disconnected organizations.

Meanwhile, trillions of digital devices, connected through the Internet, are producing a vast stream of data. All this information – from the flow of markets to the pulse of societies – can at last be turned into knowledge as we now have the computational power and advanced analytics to make sense of it. With this knowledge cities can reduce costs, cut waste and improve the efficiency, productivity and quality of life for their citizens. While these are mammoth challenges in a time of economic crisis and increased demand for services, ample opportunities for the development of innovative solutions also exist.

In November 2008, under the rubric of Smarter Planet, IBM began a conversation about exactly how the planet is becoming "smarter". Intelligence is being infused into the systems and processes that make the world work – into things no one would recognize as computers: cars, appliances, roadways, power grids, clothes, even natural systems such as agriculture and waterways. By creating more instrumented, interconnected and intelligent systems, citizens and policymakers can harvest new trends and insights from data, providing the basis for more informed decisions.

Since cities grapple daily with the interaction of water, transportation, energy, public safety and many other systems, IBM is committed to a vision of Smarter Cities as a vital component of building a Smarter Planet. A Smarter City uses technology to transform its core systems and optimize finite resources. At the highest levels of maturity, a Smarter City is a knowledge-based system that provides real-time insights to stakeholders as well as enabling decision-makers to manage the city's subsystems proactively – Figure 1 Effective information management is at the heart of this capability, while integration and analytics are the key enablers.

Instrumented
We can measure, sense and see the condition of practically everything.

Interconnected
People, systems and objects can communicate and interact with each other in entirely new ways.

Intelligent
We can analyze and derive insight from large and diverse sources of information, to predict and respond better to change.

Figure 1
Intelligence is being infused into the way the world works

B. The Smarter Cities Challenge

As IBM aligns its citizenship efforts with the goal of building a Smarter Planet, we realize that city leaders around the world face increasing economic and societal pressure to deliver new solutions rapidly, the more so given the increased demand for services. To address this, IBM Corporate Citizenship has launched the Smarter Cities Challenge to help 100 cities around the world over a three-year period become smarter through grants of IBM talent. The City of Boulder was selected through a competitive process as one of 24 cities to be awarded a Smarter Cities Challenge grant in 2011.

During May 2011, a team of six IBM executives worked in the City of Boulder for three weeks to deliver submissions on key issues for City Manager Jane Brautigam and her senior leadership team. This report provides their analysis of the capabilities of the installed smart grid and recommendations for addressing gaps.

C. Context and Objectives

The City of Boulder is a center of innovation and home to a world class research university, 14 federal research labs, visionary entrepreneurs and one of the nation's most educated populations. Boulder's history includes many ground-breaking measures that have enabled the City to offer residents an outstanding quality of life and economic opportunities.

True to its tradition as an innovator and leader, in 2007, Boulder collaborated with Xcel Energy to initiate the SmartGridCity™ (SGC) project, to build an advanced, interconnected and instrumented electrical grid with capabilities to monitor, operate, plan and meter electrical distribution in Boulder. In addition, the focus was to provide detailed information on energy usage as well as a platform for testing new pricing and demand management strategies.

The City of Boulder's main goal for the Smarter Cities Challenge is: "…making our Smart Grid Smarter by maximizing the value of the nation's first fully integrated electricity system to help Boulder achieve its energy policy goals…"

The scope of the Boulder Smarter Cities Challenge team's effort was to determine:

- What are SCG technical capabilities and their value to Boulder?
- What are the gaps in capabilities that inhibit SGC from supporting the City's energy goals?
- What are our recommendations on capabilities to grow and expand SGC in line with the City of Boulder's focus on energy and its Climate Action Plan?

Given the team's relatively short three weeks in Boulder, they concentrated on the technical implementation of SGC as it currently exists rather than a retrospective analysis of financial, schedule or technical decisions previously made. This report focuses on the technical make-up of the SGC project, how best to leverage it so as to realize the City's energy policy goals [1] and CAP, and how to enable it, with relatively modest enhancements to infrastructure, either independent of the utility or in partnership with it.

The Boulder IBM Smarter Cities Challenge team consisted of six IBM executives from around the United States, each bringing unique experiences, skills and insights to address this set of questions:

- **Brian Gaucher**, a research manager from IBM's Yorktown Heights Research Center, with a focus on Energy & Utilities and electronics research
- **Brett Hansen**, a software marketing executive from Austin, TX, specializing in software market development
- **Lisa Hopkins**, a global leader in Buildings and Sustainable Cities, from Arlington, VA, with a focus on energy efficiency, smarter infrastructure, and sustainability solutions.
- **Geoff Jue**, an Energy & Utilities industry sales leader from Woodland, MN, concentrating on smart grid strategy and implementations
- **Lauren Laplante**, a global business advisor for the Energy & Utilities industry, from Andover, MA, dealing with global E&U solutions including Smart Grid programs
- **Dejan Radeka**, a Client Technical Architect from Newport, RI, and specialist on IT Architecture across a range of industries including State Government and Energy & Utilities.

Biographies of the team members are provided in Appendix A3.

D. Approach

The IBM team received outstanding support and collaborated heavily with the City of Boulder. It met with a broad spectrum of constituents across the city. These included: Government staff and elected officials; State of Colorado government officials; concerned constituents and neighborhood associations; local business and business organizations; University of Colorado administration and research; energy experts from the National Renewable Energy Lab (NREL), National Institute of Standards and Technology (NIST), University Corporation for Atmospheric Research (UCAR) and IBM; Energy consultants retained by the City; Xcel Energy executives and technical staff.

During the first two weeks of the three-week engagement, the team conducted over sixty (60) interviews with constituents in order to understand their expectations of SGC, their perspectives of Boulder's goals, and their specific requirements of SGC going forward [A1]. The team also went on site visits to observe installed systems including visits to Xcel Energy in Denver, CO, and the NREL Wind Technology Center in Golden, CO.

At the conclusion of the three week engagement, the IBM team presented its observations and recommendations to Mayor Susan M. Osborne, the City Council, City Manager Jane S. Brautigam and her staff, and community constituents.

E. Summary Findings

The City of Boulder's SmartGridCity (SGC) has most of the advanced hardware, software, IT infrastructure and grid infrastructure to support the vision of smart grid laid out by the National Institute of Standards and Technology (NIST) [20]. It has a high-speed fiber optic backhaul network capable of accommodating increased system communication needs well into the future. It has the sensing, monitoring and control hardware and software to minimize outages, find and repair faults quickly, accommodate significant amounts of local renewable energy as well as many other features that enable a more automated system and sustainable city. However, the citizens of Boulder do not currently see any direct benefits from SGC, though initial releases on the project led to the expectation that in-home capabilities would be a component of SGC.

Boulder's SGC is analogous to a small-scale Internet-precursor, ARPANET. When ARPANET first rolled out, it provided the government with a robust, secure and high-speed communications system, but the average citizen saw no direct value for the tax dollars spent. Only as standards developed and commercial vendors began to introduce products, solutions, and content, did the citizens begin to see direct value. Today, that value is huge.

At present, SGC provides a sturdy infrastructure that enables Xcel Energy to manage Boulder's energy significantly better, with the possibility of lowering costs, while increasing reliability and sustainability. However citizens at present only gain indirect benefits with no in-home capabilities. This is akin to having an Internet without commercial vendors providing content that citizens can leverage.

What is missing in Boulder is near real-time energy monitoring and control in the home, as well as renewables and plug-in hybrid electric vehicles (PHEVs) that can be directly and jointly managed with the utility. From an energy & utilities industry perspective, the traditional responsibilities of utilities countrywide have stopped at the meter and in-home solutions are left to the consumer.

With the evolving Smart Grid, this boundary between utility and consumer responsibility is increasingly blurred and is causing consumer frustration. The Smart Grid today can be compared to an Internet waiting for web content and solutions to be developed. Fulfilling the full potential of the Smart Grid requires standards for in-home devices to be developed, security and privacy issues to be addressed, and the development of a commercial marketplace for consumer in-home energy solutions.

Home area network (HAN) standards development is underway. Security and privacy issues are beginning to be investigated and developed under the auspices of NIST and other stakeholders. Various entrepreneurs and established technology vendors are starting to produce some in-home solutions. We expect this market to develop and expand. With increased market demand, utility companies will need to respond and examine the possibility of extending their business model into the home. The overall SGC demonstration project is well positioned and well suited to this expected industry direction.

3. Technical Capabilities of SmartGridCity

Xcel Energy's SmartGridCity is a pilot project that involves various distribution system enhancements within the City of Boulder. As indicated by Xcel Energy's testimony to the State of Colorado's Public Utilities Commission (PUC) in March 2010[1], this is a demonstration project intended to test and validate a variety of "smart grid" technologies. This was one of the first smart grid projects that involved the integration and deployment of smart technologies and IT infrastructures on a demonstration basis for an entire city. The concept behind SmartGridCity is to enable Xcel Energy, its regulators and customers to obtain real information on what changes are required to operate its distribution grid to meet emerging challenges that the industry is facing [1].

The initial phase of construction began the first week of April 2008 and included the build out of core hardware infrastructure, development of new integrated software applications, and the testing and re-engineering of planning and operational processes. The final phase, which is currently underway, is the proving and deployment of premise level equipment and pricing plans. (Note that this review does not address schedule to cost issues that have surfaced over time. It only examines the technical aspects of the technology and implementation.)

As described by the US Department of Energy's National Energy Technology Laboratory and Office of Electricity Delivery and Energy Reliability [3-6], smart grid can be generally characterized by four major capabilities:

- 2-way communications
- Intelligent sensing and monitoring
- Remote control and automation
- Near real-time interaction.

SmartGridCity is an Early Mover

SmartGridCity is an early implementation of smart grids now rolling out across the nation and world [Appendix A1]. As illustrated in Figure 2 and detailed in Xcel Energy's testimony to the Colorado PUC [2], SmartGridCity contains versions of all four of the above elements. In order to assess SmartGridCity the team inventoried the hardware by reviewing a number of public documents and interviewing Xcel Energy representatives as described in detail in [7-11]. This assessment relies on those references for the following inventory.

Hardware and Software System Upgrades

SGC consists of a robust set of utility-quality hardware and software upgrades. Hardware systems that have been upgraded include the communications system, transformers and smart meters, sensors and monitors, and actuators. Components of grid operations and the IT back office have seen software upgrades, with more system-intergration. With these improvements, SGC is well positioned to implement many significant aspects of the vision of smart grids laid out by the National Institute for Standards and Technology (NIST)[20] including:

- Increased use of digital information and control technology to improve reliability, security, and efficiency of the electric grid;
- Dynamic optimization of grid operations and resources, with full cyber security;
- Deployment and integration of distributed resources and generation, including renewable resources;
- Development and incorporation of demand response, demand-side resources, and energy-efficiency;
- Deployment of "smart" technologies for metering, communications concerning grid operations and status, and distribution automation;
- Integration of "smart" appliances and consumer devices;
- Deployment and integration of advanced electricity storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles, and thermal-storage air conditioning;
- Provision to consumers of timely information and control options.

Hardware: Communications System

A secure, reliable and private high-speed fiber optic communication system (backhaul network) was installed across the entire Boulder SmartGridCity demonstration area. It runs from Xcel Energy's Control and Data Centers through the distribution substation and feeders to the transformers that feed energy to homes.

Because of the significant cost increases incurred to bury cable, the citizens, the City, and Xcel Energy have greatly debated the choice of fiber optics as the communications medium. There are other choices available: wireless for example, which while less expensive would have lower security, reliability and privacy. As this team was not able to ascertain the required metrics, it has not commented on that decision. For the purposes of this technical report, it assumes the need for a cabled solution. Note that incremental cost differences between copper and fiber cable during the time period of this project were and are minimal. Assuming that any cable, copper or fiber would have to be buried, we address only the technical choices and options for its use. As such, fiber is a solid technical choice to future-proof the system and provides an extremely robust, reliable and private network.

High-speed communication between the home and Xcel Energy's primary data center is a recent and important tool for the utility's operations. With this new capability, a signal can be sent from the utility to the home. For example, the utility could request meter information from a home and receive that home's energy usage in a fraction of a second. At present, due to technical limitations in other parts of the system, the utility currently only polls each home once a day to collect 15-minute interval usage data for the past 24 hours. (This 15-minute interval, 24-hour data is made available to the resident via the My Account portal.) It also becomes an enabling technology for future uses such as Demand Response (controlling energy use in the home to reduce peak demand) or Distributed Generation (further enabling solar or wind at the home). In interviews with Xcel Energy representatives [7], fiber optics is seen as a part of Xcel Energy's solution to enable security, privacy and reliability, as well as providing room for future expansion.

Hardware: Transformers and Smart Meters

Upgrades were made at 4,600 distribution transformers to make them "smart" in the sense that they could be monitored and fitted with secure private communications nodes. Since smart meters at the home handle a relative low data rate, Xcel Energy has chosen to convert the TCP/IP protocol (standard internet communications protocol) running over the fiber optic medium to a protocol that can run over the copper wire from the local neighborhood transformer to the home meter, called Broadband over Power Line (BPL). This BPL signal can then be routed to the meter at each home using the pre-existing power line, avoiding the installation of new equipment. The BPL signaling system has been enabled in 43,000 homes. 23,000 are within the demonstration area and thus enabled with Landis & Gyr Smart Meters and connected to the utility via this BPL signal. The remaining 20,000 homes with pre-existing AMR meters, while also connected to the utility via BPL are not officially part of the fully enabled smart grid. In the smart meter-enabled homes, energy usage is sampled every 15 minutes. This information is stored in the smart meter until polled by Xcel Energy, typically every 24 hours. When polled, the smart meter sends the stored information over the BPL link to the transformer. At the transformer, that information is converted back to TCP/IP protocol to run over the fiber optic medium and routed back to the Xcel Energy IT system processing (see SGC Enhancements to Grid Operations section below).

It should be noted that the 23,000 smart meters used in SGC do not provide a direct communications link to the inside of the home. If Xcel Energy enabled a gateway and BPL link from inside the home back to its IT infrastructure, it would allow a resident to access their meter data in near real-time and have control of in-home devices. To date, this lack of near real-time consumer level information and control has been cited as the number one reason citizens have not yet seen direct benefit from SGC. A direct communications link to the inside of the home has been discussed as one of the proposed pilots; pilots like this and others may have a dramatic impact on citizens' perceptions of its advantages to them.

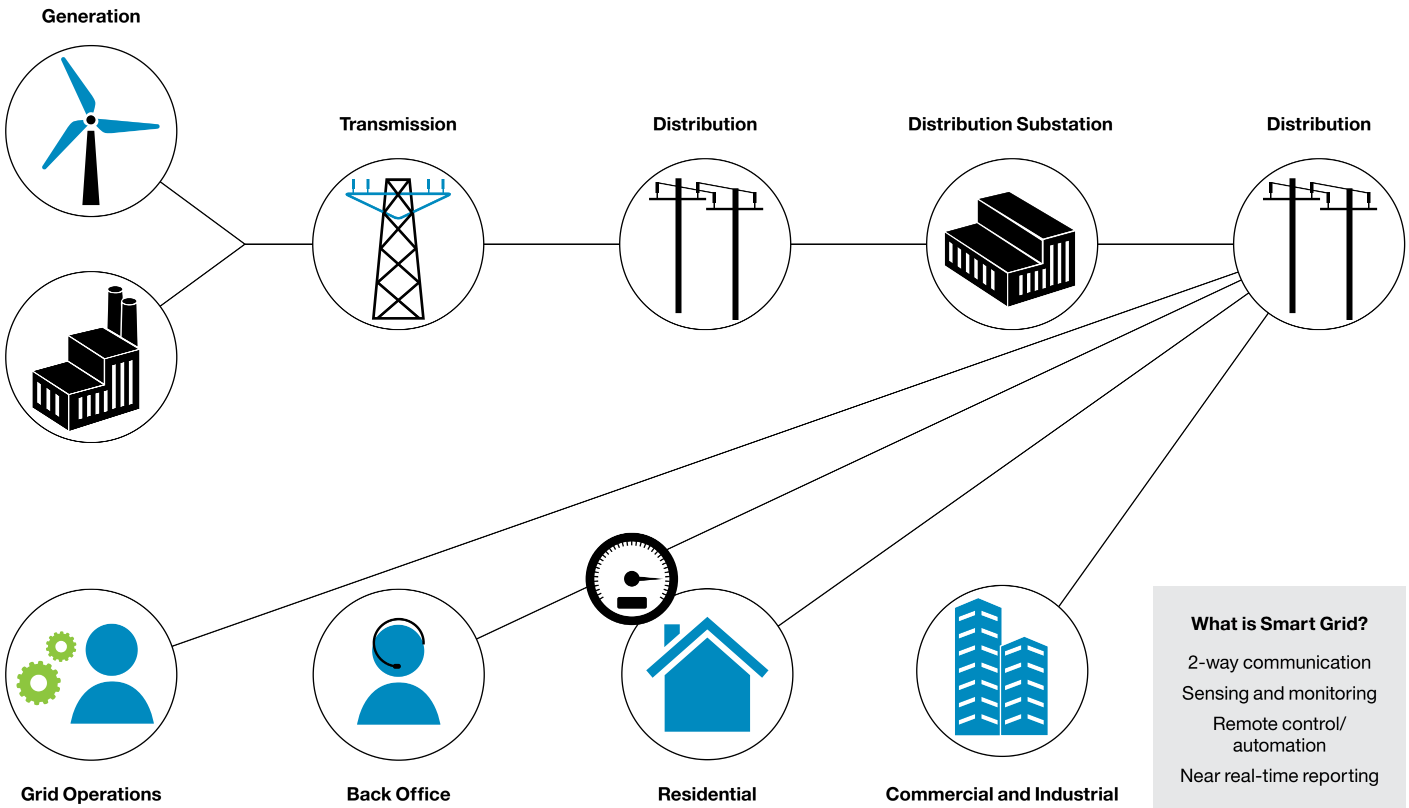

Figure 2
A generalized schematic view of SmartGridCity

Hardware: Sensors and Monitors

In addition to the 23,000 smart meters mentioned above, SmartGridCity also includes thousands of additional sensors and monitors, loosely defined here as Intelligent Electronic Devices (IEDs) distributed throughout the grid. IEDs are used to protect and automate systems. They have local control intelligence, the ability to monitor processes, and can communicate directly to the grid operations system over the communication systems. These sensors monitor parameters such as voltage, current, temperature, and many others. In addition, substation and feeder level control and monitoring systems have been installed as well as a small number of premise level systems. The City's inventory of the SmartGridCity infrastructure[8] provides additional detail on these systems.

Hardware: Actuators and Automation

SmartGridCity has also installed thousands of actuators across the demonstration area. Actuators are devices that can react to signals sent from operators in the grid operations center. Examples include switches (to route power from one location to another) and reclosers (similar to a circuit breaker in a home but with the ability to be monitored and controlled remotely, opened and re-closed). These sensing and monitoring devices and the actuators work together to form small and large remote control systems. As an example, if a tree branch hits a power line, the transformer will be able to sense that the voltage and current have changed and determine that there is a potential issue. A recloser in the system may react to that and open to stop the flow of energy in that line. It will continue to monitor that line, and once the tree branch is cleared from the line, the new measurement will indicate this and the recloser will be re-closed automatically and power restored to that line. Simultaneously the incident can be reported back to the Grid Operations center and monitored or controlled remotely. These devices are also used to enable automation of various power systems and processes.

These Upgrades Resulted in Significant Increase in the Amount of Data

In addition to the hardware infrastructure described above, major software and system enhancements have been made to enable the system to leverage the newly installed control and monitoring devices and to manage the new high volume, high-speed data produced by the daily 15-minute interval data-readings from all 23,000 smart meters. The next section addresses the software and system enhancements to enable this new set of hardware.

Software: Grid Operations

Before we discuss the necessary enhancements to Grid Operations to enable the SmartGridCity, it is helpful to understand the purpose of Grid Operations for a utility.

First, let us look at the challenges confronting the utility industry. Utilities around the globe are faced with pressures on several fronts: to improve reliability, efficiency, safety, customer satisfaction and utilization of assets; to reduce outages; to avoid new infrastructure construction; and to address environmental conservation. Second, utilities operate a myriad of disparate, legacy systems that are typically siloed i.e. not integrated with one another (see Figure 3). Lastly, a growing number of alternative energy options are emerging, including wind and solar power, electric vehicles, energy storage and micro-grids, while many customers want to be more involved in managing their own energy affairs.

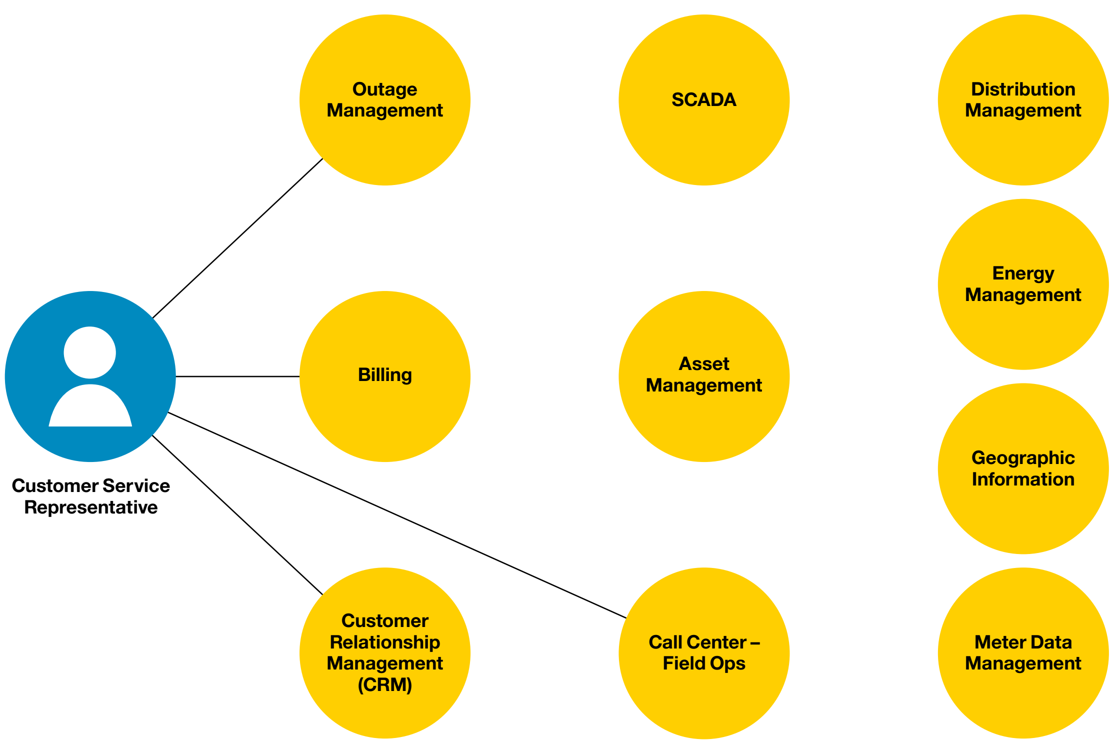

Figure 3
Disparate Grid Operations and Back Office Systems

In order to meet these challenges, utilities must integrate systems, improve operations, implement process automation, and improve, or sometime introduce, new asset management capabilities. To enable a smart grid, utility Grid Operations need to provide integrated capabilities such as grid sensing capabilities, automation systems for energy management, outage management, Geographic Information System (GIS), distribution management, supervisory control & data acquisition (SCADA), dynamic voltage optimization, demand management, and more. Grid Operations also require IT support in the form of infrastructure, data, analytics and other IT services.

Key Grid Operations enhancements for enabling a smart grid include:

- Integration of grid management systems with utility operations and business processes to enable information access for business and operations intelligence – Integration of Energy Management System, Outage Management System, GIS, Distribution Management System, SCADA (see Figure 4).
- Development of net new system capabilities – for example, Virtual Power Plant (VPP) for aggregation of distributed generation for demand response and Dynamic Voltage Optimization (DVO), which prolongs equipment life and reduces demand and the carbon footprint.
- Automation of outage and work management processes – automate outage processes from detection to resolution, enabling information access for business and operations intelligence.
- Enablement of remote asset/device monitoring and life-cycle management – remote monitoring systems for field assets and smart devices and integration of these devices with grid operations, enterprise asset management, and life-cycle management.

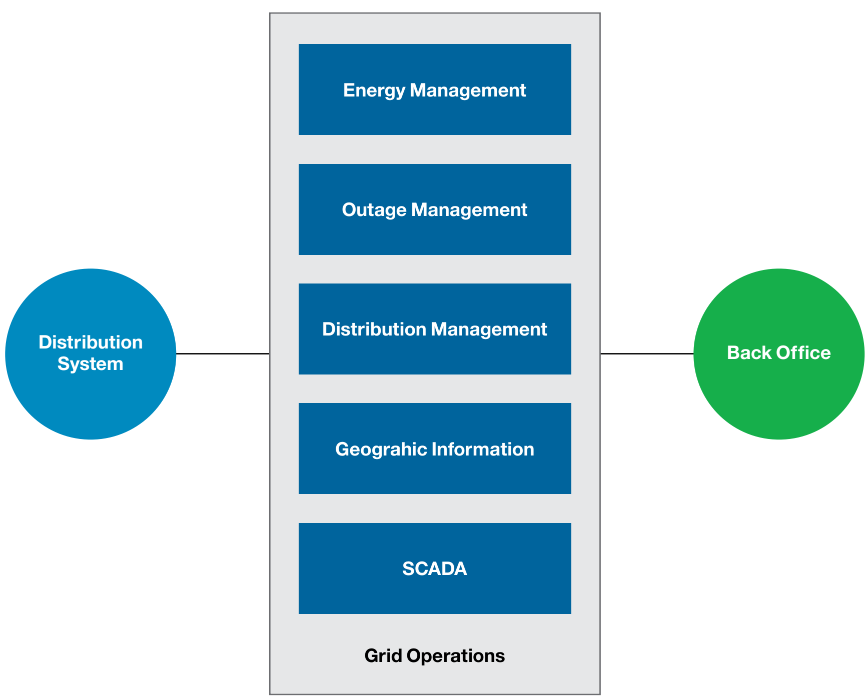

Figure 4
Grid Operations Integrated Enhancements

SmartGridCity required enhancements to many Grid Operations systems, as reviewed in Table 1:

Table 1 – Grid Operations Before and After SGC

System	Before SGC	After SGC	Benefits	Comment
Enterprise Management System (EMS)	Yes	Yes	Reliability	EMS was integrated into the Boulder environment prior to SGC.
Geographic Information System (GIS)	Stand alone	Integrated	Reliability	In Boulder, SGC led to the integration of communications infrastructure into GIS, and an integrated tool to redesign graphically both the electric grid and the communications grid during moves, adds, changes and new construction.
Outage Management System (OMS)	Stand alone	Integrated	Reliability	SGC proved that it was possible to integrate very large volumes of meter alarm data into the existing OMS system using Complex Event Processing technology. Utility benefit is that OMS does not have to be replaced prior to deployment of Smart Grid technologies in other locations.
Distribution Management System (DMS)	None	Integrated	Reliability	There was little to no DMS in Boulder prior to SGC. After SGC there is extremely comprehensive DMS to the transformer level in Boulder.
Supervisory Control and Data Acquisition (SCADA)	Yes	Yes	Reliability	SCADA was integrated into the Boulder environment prior to SGC.
Virtual Power Plant (VPP)	None	Yes	Aggregation of Distributed Generation for Demand Response	SGC implementation helped to validate the technology.
Dynamic Voltage Optimization (DVO)	None	Yes	Prolongs equipment life, Reduces demand and carbon footprint	

Software: Back Office

As with Grid Operations, a majority of utilities still operate their back office information technology (IT) systems in separate silos that are either poorly integrated or not integrated at all. With the evolution of smart grids, the utility industry must catch up in the deployment of those "enterprise class" systems that have been popular in other industries for the past two decades. With smart grids, many utilities will have to invest heavily in modernizing their back office operations to meet the requirements for integration and automation that a myriad of complex systems produce.

Utility IT departments must provide back office support in the form of communications networks, IT infrastructure hardware, software systems and cyber security, and help ensure integration under a common architecture. As a wealth of information becomes increasingly available to utilities through smarter grid investments across the enterprise, IT must also offer analytics and optimization software tools and services to allow more insight and business improvements.

Key IT functions in the back office that support smart grids are shown in Figure 5.

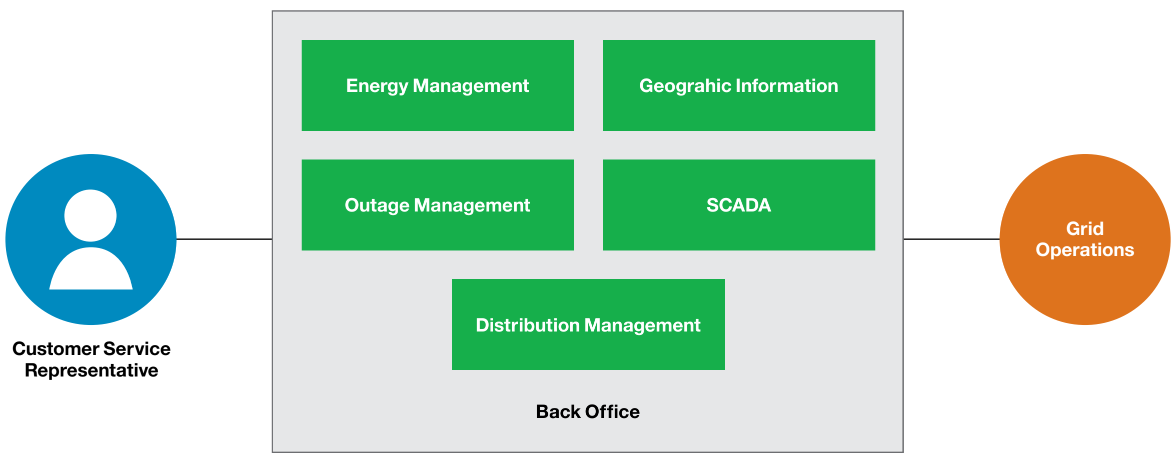

Figure 5
Back Office

Enhanced Customer Relationship Management (CRM) – these systems must manage the complete view of the customer account, and be able to integrate with modern web applications, such as portals and Web 2.0, to provide both customer service representatives and customers with online access to account information.

Call Center Integration – the call center is the first point of utility interface for an inbound customer call. It needs to be integrated with key back office and Grid Operations systems to enable the customer service representative to log the call and the problem quickly and accurately.

Enhanced Billing System – smart grids enable meter data to be collected at much higher frequencies than in traditional systems – "near real time" or "x minute" level data instead of monthly data. Enhancements to the billing system are necessary to enable utilities to take advantage of this new granular data and implement new pricing plans such as residential time-of-use or demand response pricing.

Enhanced Meter Data Management – as with the billing system, meter data management must be scaled up in order to accommodate a significant increase in the amount of data being collected by high frequency meter data reads across the grid every day. For a comparison in the order of magnitude, traditional meter read frequencies were 1 per month. Current SGC meter reads occur every 15 minutes, which equates to 2880 reads per month, per household. This exponential increase in data requires significant remodelling of the meter data management systems.

Infrastructure Planning – smart grids generate a significant amount of operational and usage data about equipment across the grid. This data allows utilities to manage and predict infrastructure maintenance and planning.

Asset Management – the increased complexity of equipment and new monitoring data from new hardware requires automation, analysis and insight for optimized asset management across the grid. In addition, the thousands of meters, sensors, actuators, and other intelligent devices installed in the field need to be tracked, maintained and upgraded over time.

Customer Portal – Utilities must modernize their interaction with their customer to meet current customer expectations. Many customers want to use web portals to check their accounts, monitor their appliance usage, perform usage analysis, interact with other like-minded customers, automate their home, and pay their bills. Further interactions might even include outage reporting and management, along with automated customer communications via email or SMS.

In addition to the systems described above, utility IT departments must also provide analytics and reporting capabilities, including:

- **Reporting and regulatory compliance** – documentation, compliance and reporting management systems to comply with and automate government mandated reporting and compliance regulations.
- **Informed decision making** – analytics and optimization software toolset and services to enable the transformation of data into integrated and trusted information and drive improved performance across the utility.
- **Cyber security** – a combination of cutting-edge technology and proven security expertise to build a proactive, integrated approach to managing cyber security risks, costs and regulatory compliance.

SmartGridCity has required enhancements to many back office operations systems, as reviewed in Table 2:

Table 2 – Back Office Operations Before and After SGC

System	Before SGC	After SGC	Benefits	Comment
Customer Relationship Management (CRM)	None	Integrated	Customer insight	Customer accounting systems but no formal Residential CRM existed prior to SGC.
Call Center Integration	Manual	Integrated	Insight, quality, accuracy, Improved response	Includes the ability to run remote diagnostics to the meter from the Call Center.
Billing	Monthly meter data	Capable of 15 min meter data every 24 hours	Fine grained usage statistics	Utility targeting 15 minute on demand data 3Q 2011.
Meter Data Management	Monthly	15 minute meter data	Usage insight, demand response	Exponentially more data for the utility to manage.
Infrastructure Planning	Manual, limited insight	Analytics, insight	Reduced capex, equipment longevity	
Asset Management	Manual, limited insight	Demand response, analytics, insight	Reliability	
Customer Portal – CRM	Not integrated	Integrated	Ease of account inquiry and payment	Utility continues analysis on how best to provide more capability.

SmartGridCity – Impact on Renewables

With an understanding of the utility enhancements to Grid Operations and back office operations in SGC, we can review how these systems affect the introduction and integration of renewable energy to the grid. Please refer to Table 3 below. For complete definitions of the cited capabilities please refer to Appendix A1.

Table 3 – Impact on Renewables

Capability	Before SGC	After SGC	Benefits	Comment
Masked Demand	No	Yes	Reliability, reduced cost	
Unknown Reverse Power Flow	No	Yes	Safety, reliability, reduced cost	
Substation and Network Upgrades	No	Yes	Reliability, intelligence, private, secure	Utilities do regular substation upgrades across their service area – however, SGC led to Boulder getting these much sooner than they would have and in a more advanced fashion.
Edge Point Variation (EPV)	No	Yes	Reliability	Utility was aware of EPV before SGC; however SGC facilitated impact analysis, data collection and possible mitigation strategies.
Transformer Monitoring	No	Yes	Reliability, intelligence	
Clustering	No	Yes	Aggregation, virtual power	
Solar Rewards	Yes	Yes	Value proposition for customer	
Decoupling of Costs	Yes	Yes	Value proposition for customer	SGC has driven greater industry awareness of this issue.
Net Metering	Yes	Yes	Value proposition for customer	SGC helped utility identify the issue of needing to be able to modify regulatory environment to install a single universal meter in the future.
Virtual Power Plant	No	Yes	Reliability	
Provider of Last Resort	Yes	Yes	Reliability	
Communications Standards	No	No	Need to develop industry market	All utility infrastructure developed using currently available industry standards. Home Area Network (HAN) market still evolving.
Customer Data Privacy	Yes but limited understanding	Major Issue	Not yet fully understood	A core issue in how to handle the vast amounts of new information that a smart grid will generate.

4. Assessment of Capability Gaps

Approach to Gap Analysis

As the previous chapter described, there are numerous capabilities and benefits associated with SmartGridCity (SGC) project. This chapter will review a number of capability gaps associated with SGC, some owned by the utility directly and others shared between the utility and end-user customers. This assessment is based on our knowledge of SGC from interviews with Xcel Energy, the community, and what background material we were able to absorb during our three-week effort. We also leveraged our collective knowledge of smart grid deployments around the world.

An important related point to make about our assessment is that SGC was a demonstration project to test new technologies and validate value propositions. It is also our experience that every smart grid project is iterative and continuously evolves and improves based on new information from the system. Much of the frustration with SGC is due to the mismatch between Xcel Energy's early communications around project goals and the current capabilities of the installed system, particularly in what is available in the home.

In 2008, Xcel Energy published a smart grid white paper that outlined their three-phased approach to smart grid implementation. This included (1) a number of quick hit projects to demonstrate smart grid concepts within each component of the utility value chain, (2) SGC planned deployment from 2008-2010, and (3) further deployment of proven technologies based on the experience of the first two phases. [1]

As previously mentioned, the energy & utilities industry entry into smart grid technology is still in its early stages, akin to the early stages of the commercialization of the Internet. The industry has not yet figured out how to articulate the benefits to the individual and to communities of smarter energy. The traditional utility business model does not support much interaction or communication between the utility and the customer. As a result, consumers have not yet embraced their more active role as full participants in a truly networked, multi-stakeholder system. Lastly, the commercial marketplace for the development of consumer energy products and services is still evolving and immature. Until all three of these attributes develop, the full potential of the smart grid will not be realized. While the progress of technology is accelerating, the utility, the marketplace, and the consumer must also evolve.

Utility responsibility	Utility and customer responsibility
1. Aggregate customer demand	7. Renewable integration
2. Near real time data access	8. Plug-in Hybrid Electric Vehicles (PHEV) integration
3. Demand forecasting for grid operations	9. Interoperability in-home exchange
4. Predictive grid operations	10. Data access beyond the meter
5. Small and Medium Businesses (SMB) Commercial & Industrial (C&I) engagement	
6. Dynamic pricing	

Figure 6
Capability gaps of SmartGridCity, divided into utility responsibility and utility and customer responsibility

The top capability gaps we identified around the SGC demonstration project are illustrated in Figure 6 and described in greater detail below:

Aggregation of customer demand – Demand aggregation is the means of combining the loads of more than one electricity user with the goal of incorporating this into coordinated peak shaving, or shopping around the electricity supply market to get a better price for power. The more granular the load information, the more specific and targeted the program can become.

Data access and ability to respond in near real-time – This refers to the ability of the customer to gain access to their near real-time data and for smart meters to send data back to the utility in near real-time.

Demand forecasting for grid operations – The utility's ability to incorporate the users' loads into their distribution and supply side planning operations.

Predictive grid operations – The utility's ability to apply analytics to build predictability into the operation of the grid, thus increasing reliability and shortening resolution times.

Small medium business, commercial & industrial engagement – This segment of the market is particularly challenged to find ways to directly leverage SGC. Indirect benefits may come in the form of increased reliability, faster resolution time, and rate stability, but direct benefits from energy efficiency programs and load shifting are limited and difficult to manage economically.

Dynamic pricing – Dynamic pricing or "real-time pricing" is the ability to provide price signals to the user on an advanced or forward basis, reflecting the utility's cost of generating and/or purchasing electricity at the wholesale level. Electricity prices typically change on an hourly basis.

Renewable integration – The development of renewable energy and the integration of renewables into the grid comes up against many challenges: the siting and building of new transmission; the permitting of new renewable generating facilities; the appreciation of the impacts of distributed renewable generation on the grid. The gap lies in the incorporation of larger-scale renewables into the grid along with storage.

Plug-in hybrid electric vehicle (PHEV) integration – Integrating electric vehicles into the distribution grid and managing the stability, safety, security, and utility infrastructure. This also includes storage integration and innovative pricing plans that incentivize the user to charge their vehicles during non-peak times and when the distribution grid can handle the load without negatively impacting other clients or equipment.

Home device interoperability and data exchange – This is the ability for appliances to communicate with each other. This would help enable demand aggregation.

Utility data access beyond the meter – The ability for the utility to access appliance-level information beyond the meter. This would require the user to install home devices that would communicate with the utility.

How the Capability Gaps Correlate to the City of Boulders's Energy Goals

After identifying the key gaps in SGC capabilities, we correlated these gaps with the City's Climate Action Plan and the needs of the community. We assessed the impact of closings the gaps on those elements most important to the City of Boulder – reliability, rates, renewables, and energy efficiency. This view could help determine which goals are most impacted by addressing a particular gap (Figure 7).

The four capability gaps with the greatest impact on the City's energy goals as well as the needs of the community are:

- Engagement with small and medium businesses
- Renewable integration
- PHEV integration
- Data access beyond the meter.

	Reliability	Rate	Renewable	Energy efficiency
Aggregate customer demand			🟢	🟢
Near real time data access		🟢		🟢
Demand forecasting for grid operations	🟢		🟢	
Predictive capabilities for grid operations	🟢		🟢	
Commercial & Industrial (C&I) incentives for Small and Medium Businesses (SMB)		🟢	🟢	🟢
Dynamic pricing		🟢		🟢
Renewable integration	🟣	🟣	🟣	🟣
Plug-in Hybrid Electric Vehicles (PHEV) integration	🟣	🟣	🟣	🟣
Interoperability in-home device exchange				🟣
Data access beyond the meter		🟣	🟣	🟣

🟢 **Reflect gaps that are primarily owned by the utility**

🟣 **Reflect those that are jointly owned by the utility and end-use customer**

Figure 7
Gaps correlated to Climate Action Plan (CAP)

Prioritizing the Capability Gaps

We also assessed the degree of difficulty and length of time it would take to close each of the capabilities gaps. We created a view of those future capabilities that were relatively easy to implement (level of difficulty) against the time to implement (Figure 8). The relative size of the impact of these gaps on the COB's energy plan, are reflected in the size of the circles. The red circles represent those that are utility-dependent, blue are customer-dependent, and purple correspond to those gaps that are dependent on both the utility and client alike. This SGC opportunity assessment provides a helpful way to target the activities that provide the highest, speediest return with the least amount of effort. These are reflected in the top right hand quadrant of the bubble chart in Figure 8.

Through this opportunity assessment exercise, the gaps that should be addressed first include:

- Renewable integration (Bubble 7)
- Access to near real-time information (Bubble 2)
- PHEV integration (Bubble 8).

It is interesting to note that two of the highest priority gaps identified from these two perspectives are the same – renewable integration and PHEV integration.

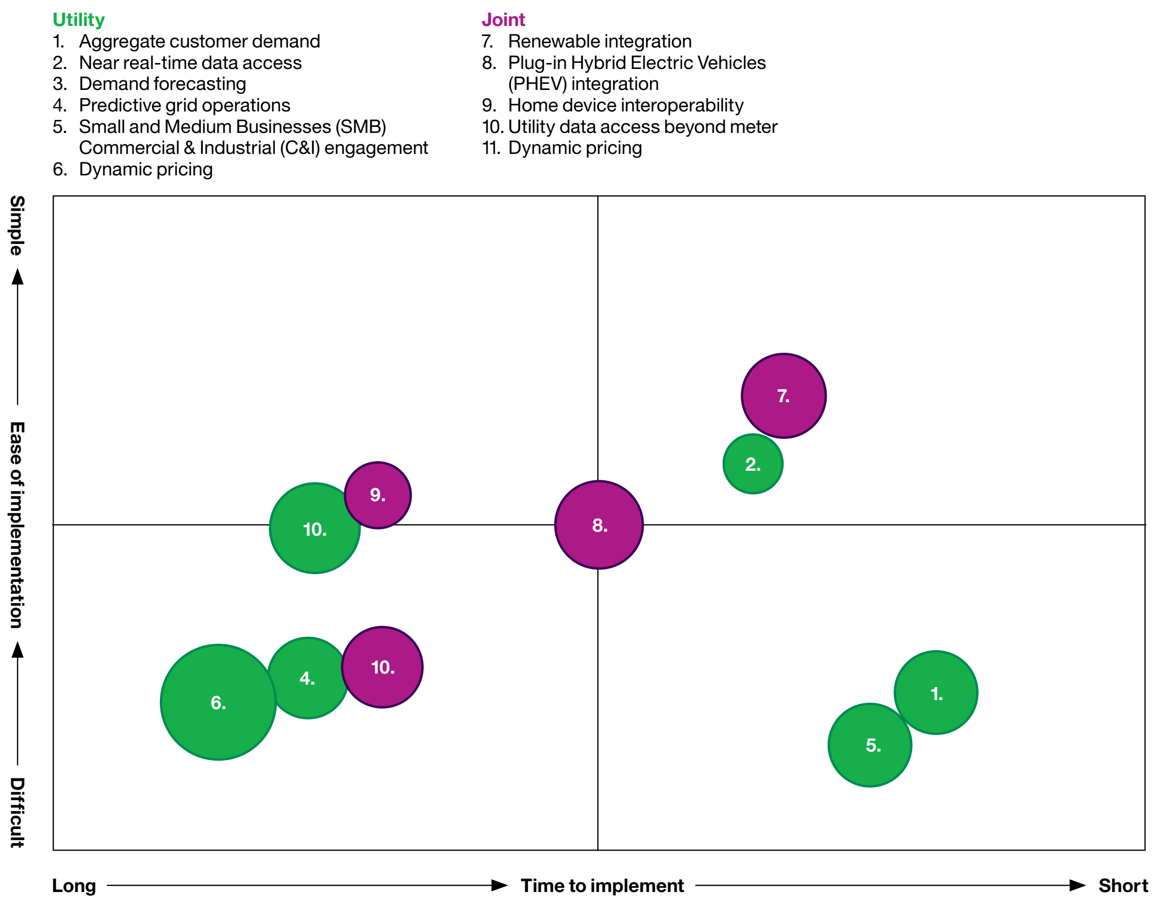

Figure 8
Opportunity assessment

5. Recommendations and Pilots

Our analysis showed that the City of Boulder can gain the greatest benefit with least effort and cost by focusing on increasing renewables, PHEVs, and demand side management (DSM) beyond the meter, specifically with the small and medium businesses (SMB) segment.

A. Recommendations for Increasing Renewables

Increase (Local) Distributed Generation

The City should investigate how best to increase local penetration of distributed generation such as Solar PV on rooftops. Working in partnership with NREL and Xcel Energy, the City should assess the available capacity for rooftop solar power in Boulder, and how to optimize the installed smart grid to facilitate increasing the penetration of local solar power.

Investigate Renewable Energy Storage Options

To enable more consistent power, grid energy services companies are expected to install energy storage equivalent to 1 – 3 percent of installed solar capacity. From the perspective of renewable integration, incorporating energy storage offsets the intermittent delivery of renewable energy to create consistent dispatchable power. For example, at the Solar Technology Acceleration Center (SolarTAC) in Aurora, CO, a 1 MW storage facility will be used for power smoothing and time shifting. This technique allows for solar energy generated during the day to be utilized during off-peak hours. This project is being managed by Xcel Energy and Xtreme Power. [1]

The City should investigate options for promoting investment in renewable energy storage to facilitate the integration of increased renewable sources into Boulder's energy supply. For example, the Federal Storage Act of 2010, proposed by Ron Wyden (D – Oregon) proposes a 20 percent investment tax credit for energy storage. [2]

Develop a Renewable Energy Portfolio

The City should partner with Xcel Energy and other potential investors to develop a renewable energy portfolio t o hedge against potential future increases in power costs. This effort should assess Colorado-based as well as out-of-state renewable energy options within Xcel Energy's transmission infrastructure. It should:

- Increase participation in regional renewable energy
- Invest in regional or other renewable energy facilities
- Partner with renewable energy investment firms
- Develop a portfolio of renewable energy Power Purchase Agreements (PPAs)
- Develop a portfolio of Renewable Energy Credits (RECs)
- Partner with PUC, NREL and Xcel Energy to develop innovative renewable energy incentive programs.

Solar rewards and other incentives have been diminishing over time, as the technologies have increased in capacity and costs have decreased. The City should partner with NREL and Xcel Energy and work with the PUC to help develop new renewable incentive programs for the State of Colorado to encourage continued investment in research, development and adoption.

B. Recommendations for Pilots

In addition to the recommendations laid out above for increasing the integration of renewables, we recommend that the City work with partners to undertake a small number of pilot projects to demonstrate the value of the smart grid. Our recommendations are informed by input from all the constituents we interviewed as well as our combined professional experience, working with clients on smart grid pilots.

1. Solar & Plug-In Hybrid Electric Vehicle (SPHEV) Self-Sustainability Pilot(s)

The City of Boulder should consider a pilot that maximizes the use of solar panels to provide battery-charging for electric vehicles. Given the topography of the grid and the City's wish to supply as locally as possible, photovoltaics present the best opportunity for local renewables in Boulder. Joe Castro of Boulder Public Works is extremely interested in this type of pilot, as are other partners in the city, and there also appear to be government funding opportunities.

In an SPHEV pilot, the charge for electric vehicles comes from locally available, renewable energy in the form of solar power, thereby impacting two of Boulder's primary energy objectives – increased renewables and increased supply of locally generated power.

Solar power could come from rooftops and/or local solar gardens, which would provide the energy to the vehicle charging stations. The goal is to obtain a net zero (no energy fee) charge or to sell the solar power back to the grid for a net positive transaction.

One can expand the concept of the SPHEV pilot through neighborhood challenges, while also offering the idea to retail developers and commercial property owners. Both expansion models are further detailed below.

The City will need to be aware of a few major challenges as it embarks on such an effort. These include:

Billing – at present, if a PHEV vehicle pulls into a public charging station, there is no simple electronic means to associate a vehicle with an owner; an attendant would be required to facilitate that exchange. The vehicle would need to be modified to automate this. Nissan and/or Toyota, in partnership with Xcel and the City, could make the necessary vehicle modifications to enable electronic billing.

"Green Energy" delivery – new infrastructure will be required to facilitate the transport and metering of solar-generated energy from gardens or rooftops to the charging stations, thereby confirming the City's local "Green Energy" to citizens. Xcel could help to modify aspects of SGC to create this system and process, while the City could manage its use.

Storage – given the intermittent nature of solar power and vehicle charging, the City and Xcel should consider some amount of storage for the solar gardens or rooftops that would create and supply "Green Energy". Some form of nominal storage would buffer these intermittency issues and enable a more stable system and constant source of "Green Energy."

SPHEV Neighborhood Challenges – the neighborhood challenge would, for example, pit two or more neighborhoods in a competition to obtain the greatest electric vehicle miles driven and to generate the most revenue from selling power back to the grid.

SPHEV Shopping Centers – with public electric vehicle charging stations in the parking lot, a shopping center owner/developer could feasibly attract more business to their individual stores or consortium. One retail space could be a "Solar Charging Café" in which there are customer incentives, e.g., discount coupons, to drive electric and charge solar.

2. Illustrative Buildings pilot: Promoting Energy Efficiency through Green Infrastructure Management

Vision

If you sit in a conventional office building, take a moment to listen to it hum and breathe. The HVAC system, the lights, the water, the elevators, the power and cooling for technology, the heating and cooling for people: all contribute to making buildings a significant source of direct and indirect greenhouse gas emissions – and high consumers of energy. Looking at it from a sustainable resource use and management point of view, 40 percent of the world's current output of raw materials goes into buildings, about 3 billion tons annually.

Through our brief research on the SGC pilot, energy consumption in Boulder's larger buildings stock including commercial, university and public sector buildings, is a leading contributor to Boulder's energy use profile (60-80 percent by recent estimates). It is thus of prime significance in tackling the City's energy goals. The City can serve as a model for others, leading the way with sustainable and replicable power supply operations, demand management and sustainable upgrades – whether in one or multiple dispersed buildings, and with communities connected to the grid. See Appendix A7 for more details on a Buildings Energy Efficiency pilot.

Approach to Increased Energy Efficiency in Buildings

The City should target a set of SMB clients and develop a pilot for demand side management, energy efficiencies, renewables control, and other measures to help reduce the utility bill while achieving a greener approach to energy usage.

A Move toward Green Infrastructures for Boulder

Imagine a Boulder that is 'green ready' in all public facilities and infrastructures. The City should build on the success of its residential energy retrofit program to offer incentives to developers to build or retrofit green infrastructures, for example, installing solar panels on office building roof tops and on shopping centers.

The City should also consider implementing tracking and safety mechanisms such as electric vehicle registration and inspections, charging station licensing, permits and inspections (schedule similar to elevator inspections).

3. Small and Medium Businesses Energy Efficieny Pilot

Buildings also have the ability to become energy providers to the smart grid. With such an emphasis on buildings and the strong Commercial and Industrial (C&I) makeup of the City of Boulder, a pilot in the C&I space would be beneficial. In particular, small and medium businesses (SMBs) currently receive minimal direct support in energy conservation through education and incentive programs. A targeted effort, leveraging SGC capabilities and analog efficiency improvements may provide significant value.

Initial and independent options with a reasonably rapid return might include:

- Creating targeted programs that educate small C&I owners and tenants.
- Collaborating with Xcel Energy to develop optimized rebates and incentives for SMB clients.
- Targeting 2-3 of the largest energy consumers to retrofit systems such as lighting, HVAC and water heating.

Longer-term options might address:
Partnerships with NREL, CU, and Xcel Energy to explore the use and optimization of renewables.

C. A Sample of other Smart Grid Projects Around the World

Smart grid initiatives around the world are quite varied in approach, technologies, and purpose. The focus of their initiatives differs according to the needs of utility, client, and community. Consequently, no two implementations are alike. Furthermore, the roadmap to each individual smart grid initiative is also unique as it takes into account individual budget, timelines, systems, resources, and other business priorities.

Given this, much can still be learned from the global deployments of smart grids. A good example is the Olympic Peninsula GridWise Project, funded by the US Department of Energy from 2004 – 2007, where dynamic price control was successfully tested. [1]. In this case, the smart grid enabled a simple client response that was automated and had the right incentives built in to reward behavior.

This section provides an overview of leading smart grid initiatives around the world.

Localization and Island Markets

From the localization perspective, Boulder can be seen as an (electrical) island. From this viewpoint, it is valuable to consider what other island markets are doing with respect to smart grid. Here are two examples:

Bornholm

The island of Bornholm, off the coast of Denmark, is conducting a pilot to use renewables to power electric vehicles but is focused on maximizing wind energy. This is known as the EDISON project.
http://ec.europa.eu/enterprise/archives/e-business-watch/studies/case_studies/documents/Case%20Studies%202009/CS09_Energy2_Edison.pdf

Malta
The island nation of Malta, off the coast of Italy, has embarked on a long range effort to make all of the island's utilities systems smart through remote monitoring, automated meter-reading and management of the networks. Time of day pricing is being implemented and island residents will be able to track their energy usage online.
http://www-03.ibm.com/press/us/en/pressrelease/26596.wss

Integration of Renewables

City of Mannheim
The City of Mannheim, Germany, has embarked on creating a smart city. It is implementing an integrated power management framework to accommodate multiple energy sources, including that produced by "prosumers" – consumers with the local means (e.g. solar paneling) to produce more energy than they consume.
http://www.smartgrid.epri.com/doc/10-ModelCityMannheimProject-Buchholz-Nice09122008.pdf

Burlington Hydro, Inc.
Burlington Hydro, Inc. of Ontario, Canada has announced a GridSmartCity™ in which it plans to pilot programs in energy conservation, system intelligence and renewable energy. There are many partners involved in these programs. City of Boulder may wish to consult with Burlington Hydro, Inc., to understand these initiatives, how they are funded, how GridSmartCity works and how it is managing relationships amongst all constituents.
http://www.gridsmartcity.com

Automated Energy Management/Conservation – Large Residential Deployment

IBM & Energy Consultant Hildebrand
A UK utility needed a way to scale up its energy monitoring solution and monitor three million homes. The solution enables real-time analysis of electricity usage for households or individual appliances, helping people make better decisions about energy efficiency.
http://www-03.ibm.com/press/uk/en/pressrelease/31732.wss

http://www.elp.com/index/display/article-display.articles.electric-light-power.meetering.2010.05.IBM__Hildebrand_to_bring_smart_metering_to_U_K__homes.QP129867.dcmp=rss.page=1.html

Automated Energy Management/Conservation – Large Residential & Commercial

Oxxio Metering
This utility was looking to expand services. Their solution gathers energy demand data from "smart" meters for customer viewing, increasing customer retention and promoting conservation.
http://www-2000.ibm.com/partnerworld/pwhome.nsf/weblook/pat_sol_green_oxxio.html

DONG Energy
The largest utility in Denmark, DONG Energy strategically monitored the grid to improve performance, e.g. reduced outage minutes by 25 – 50 percent, resulting in improved capital savings on planned grid upgrades.
http://www.dongenergy.com/en/business%20activities/distribution/electricity_distribution/pages/future_energy_grids.aspx

Remote Control – Interoperability

Pacific Northwest National Laboratory

A standardized device for gateways and devices that communicate with the gateway, to keep the electrical grid healthy in times of stress. Achieved by managing electrical demand through a combination of intelligent technology and financial incentives.
http://www.pnl.gov

Pilot Pricing Plans

Keep the electrical grid healthy in times of stress by managing electrical demand through a combination of intelligent technology and financial incentives.
http://www.pnl.gov/topstory.asp?id=285

Automated Water Management

Dubuque, Iowa

The City wished to conserve water and avoid wastage. It leveraged information, alerts and insights to encourage changes in behavior, resulting in conservation and the fixing of leaks.
http://www.cityofdubuque.org/index.aspx?NID=1348

Grid Operations

CenterPoint Energy

A Houston, TX utility needed to deliver power more efficiently and reliably in the face of growing consumer expectations, environmental concerns and increasing costs. The company also saw the opportunity to break new ground in grid management practices.
http://public.dhe.ibm.com/common/ssi/ecm/en/euv03003usen/EUV03003USEN.WMV

Ausgrid

Sydney, Australia-based utility wanted to improve its ability to pinpoint faults by location and type and to replace manual network monitoring procedures with a real time "digitally aware" solution that would gather network data directly into its network operations center (NOC).
http://www.ibm.com/smarterplanet/global/files/gb__en_uk__cities__smarterplanet_Energy_Australia.pdf

Other energy related projects, materials and references can be found on IBM's Energy & Utilities Industry website at http://www.ibm.com/energy

Other energy and utilities related case studies can be found here.
http://www-01.ibm.com/software/success/cssdb.nsf/industryL2VW?OpenView&Count=10&RestrictToCategory=corp_EnergyUtilities&cty=en_us

Smart Infrastructure for Highways

Pacific Coast Collaborative

Four U.S. states, Alaska, California, Oregon, Washington together with British Columbia, Canada are developing the first green highway along Interstate 5 to accommodate alternative fuel vehicles.
http://www.pacificcoastcollaborative.org/priorities/transportation/Pages/GreenHighways.aspx

6. Project and Program Management

Project Planning is Essential to the Success of Smart Grid Pilots

We recognize that the City of Boulder is an established leader in deploying smart grid solutions and is already doing project and program management. However, given that smart grid pilots typically involve many stakeholders and time sensitive deliverables, we feel it worthwhile to highlight a few areas: it is important to have published project timelines, expectations and metrics such that all parties can contribute and be held accountable.

Once a pilot is chosen, it is essential to follow a traditional project management approach in which clear, measureable goals are set. Sample energy project goals are shown in the top half of Figure 9 below. Once metrics are identified, a baseline of metrics values must be established. From here, target metrics for a future date, for example, 5 years out, can be set.

Boulder has published a CAP but it is difficult to create an achievable roadmap without first having a clear set of measurable goals

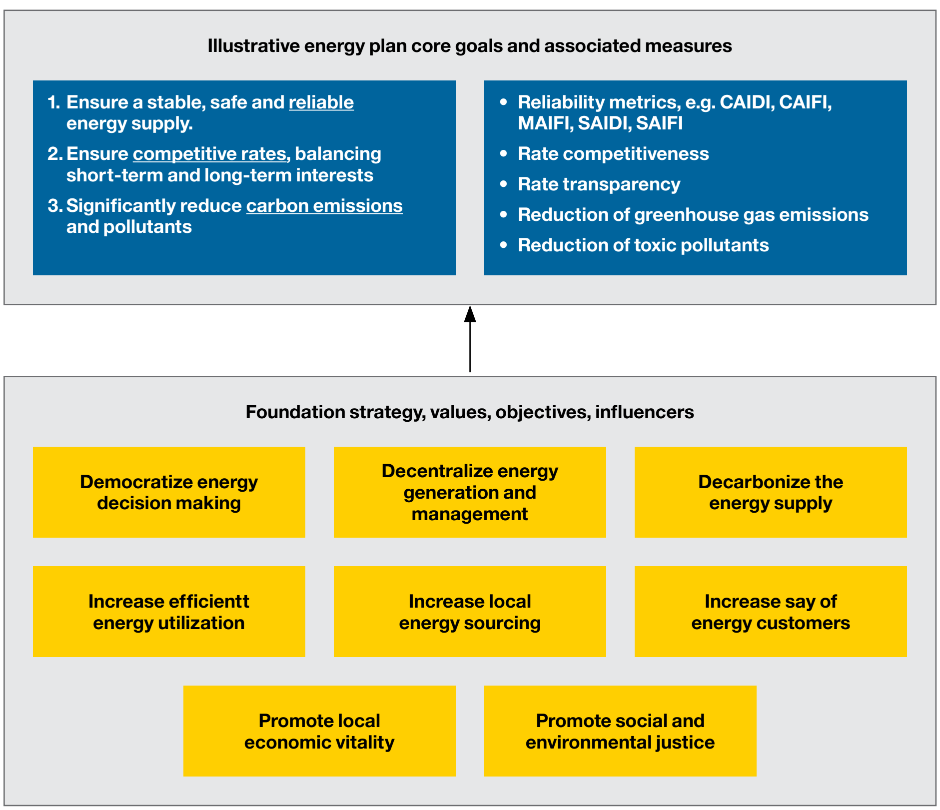

Figure 9
Example Plan toward Boulder core goals

Given the passionate opinions around energy, it is important to distinguish measureable goals from core values, foundational strategies and objectives. Some examples of core values which are important to the social fabric of Boulder include democratization of energy decision-making, the increased say of energy consumers, and the promotion of social and environmental justice.

A Program Management Office (PMO) is Essential to Coordinate all Energy Related Initiatives

Boulder's energy objectives affect multiple City initiatives from Economic Vitality to Regional Sustainability. It is important to have a Program Management Office (PMO) to ensure overall alignment and coordination of metrics tracking, project interdependencies and efforts. The PMO focuses on maximizing efficiencies and results, and realising benefits across all of the projects.

Energy Related Education and On-Going Communications

Education and Communications for Energy-Related Programs

Energy is an important issue to everyone and especially to the City of Boulder. The City should continue providing information on the status of energy-related programs. We recommend that the City of Boulder publish annual metrics reports focused on the chosen measureable goals that provide local metrics and compare these to state and national statistics. The reports might contain information on reliability metrics, generation supply mix such as percentage of power from renewables, and carbon footprint statistics.

Education and Communications for Smart Grid Pilots

Initial and on-going education together with communications, are important in raising awareness and aligning constituents' expectations with the smart grid pilot project timeline and all programs overseen by the PMO.

Funding for Smart Grid Pilots

Pilots of any sort can be costly. Smart grid pilots can have the added complication of deploying pre-mainstreamed technologies. Creativity and collaboration are required to find and develop funding opportunities Funds should be sought from multiple sources, for example:

- Government agencies, i.e. National Labs, and County, State and Federal governments
- Grants for special causes such as for low income housing
- Non-profit agencies with interests in the environment, sustainability and the rest.
- Vendors, that is, software providers, automotive electric vehicle providers, energy management services providers
- University research resources
- Private residents and citizens.

Investors and donors can gain marketing visibility for their organization by supporting Boulder's efforts to offer local, renewable power resources. Market the opportunity to be part of the first SmartGridCity and help to make it even smarter and greener by leveraging local, sustainable, energy.

In the spirit of localization, we recommend pursuing funding from third parties and partnering with knowledgeable and interested parties like NREL, CU Boulder, Xcel Energy and others in the Boulder area.

7. Appendices

A1. Definition of Smart Grid Capabilities Discussed in Chapter 3

Capabilities that Affect Reliability

Masked Demand

Masked Demand is the difference in power demand that the utility needs to accommodate when confronted with an unexpected loss of available generated power from renewable energy sources, in particular when those renewable sources are located on the load side of the meter. For example, when a neighborhood of residential power customers who have solar PV on their rooftops experiences a sudden change in weather, there is a sudden drop in generated power on the load side of the meter(s). These homes still have a need for power at a specified level. The utility must have enough generating capacity to serve this "masked" load. This problem could be multiplied across the grid. With the implementation of enhancements to IT systems within the grid operations center that supports SmartGridCity, the utility is aware of this masked demand and can therefore be prepared to serve this load. See also "Edge Point Variation."

Unknown Reverse Power Flow

Unknown reverse power flow refers to power placed onto the grid from load side renewable power sources on the system – for example, a homeowner who does not report the installation and operation of a solar PV rooftop system. With the implementation of smart meters the utility can see both forward and reverse power flows and therefore determine if someone is putting reverse power flow onto the grid. [18]

Substation and Network Upgrades

To support renewable power sources on the load side, the utility must upgrade substations and the network. The utility has upgraded substations to "smart" substations for monitoring, while the communications network has been upgraded to utilize a fiber optic backbone – a TCP/IP (Industry standard internet protocol) based, secure private network. [18]

Understanding of Edge Point Variation

Power demand varies as more customers are brought onto the grid, and also as more renewables are introduced on the load side of the grid. The magnitude of the variation will grow as more renewables are brought in due to technological advances, increased availability and capacity, and affordability through cost decreases, which will raise community demand. The variation in demand is also affected by environmental factors that are outside our control, such as weather. Edge Point Variation is the monitoring and analysis of this demand variation. In order to minimize the effects of Edge Point Variation, a utility must understand the metrics and patterns across its grid and be able to respond to them. The utility has to automate this process. From an infrastructure perspective, the utility needs to upgrade substations to "smart" substations which can monitor feeders and respond dynamically to load variations. From an IT standpoint, the utility upgrades and/or further develops the DMS and SCADA systems to support this. This analysis and response is optimized so that the utility can determine where to invest in grid infrastructure to maximize reliability, while managing capital and operational costs.

Transformer Monitoring

Approximately 4600 transformers were upgraded to "smart" transformers. These transformers are capable of being instrumented for monitoring the grid, power demand, voltage, and environmental factors. Each is paired with a "Network Element," a "ruggedized" CPU running the Linux operating system and software for security and protocol translation which is mounted on the utility pole next to the transformer. Specifically, the Network Element provides the authentication and encryption (elements of network security) and the communication bridge between the BPL communication from the Smart Meter, and the TCP/IP (Industry standard internet protocol) running over the Fiber network back to the Utility Back Office data center.

For example, weather instruments can be installed and monitored via the new communication network. This allows the utility to monitor weather conditions in specific geographic areas. This data can be used to anticipate changes in weather that may affect the output of power being generated by load side, distributed generation (homeowner) solar PV. Operational data about the transformer (such as operating temperature, which can affect the longevity of the transformer) can also be monitored. This data allows the utility to react to variability in demand, and manage the assets. See also "Masked Demand" & "Edge Point Variation." In another example, homeowners with plug-in electric hybrid vehicles (PHEVs) unknown to the utility can put significant unknown demand on a transformer, causing variability in power as well as damage to transformers.

Capabilities that affect Renewable Integration

Clustering

Clustering of solar power on the load side of the grid is sometimes referred to as aggregation, or can also be referred to by some in the industry as a "micro-grid."

A micro-grid is defined as a localized grouping of electricity generation, energy storage, and loads that normally operates connected to a traditional centralized grid, or macro-grid. This single point of common coupling with the macro-grid can be disconnected. The micro-grid can then function autonomously. Generation and loads in a micro-grid are usually interconnected at low voltage. From the point of view of the grid operator, a connected micro-grid can be controlled as if it were one entity. Micro-grid generation resources can include fuel cells, wind, solar, or other energy sources [20].

For example, clustering or aggregation of solar power by several homeowners served by a transformer in a neighborhood would create a micro-grid. In this scenario the power that is generated by multiple distributed generation systems is pooled and can be sold back to the utility. The Smart Grid technology would utilize coordinated control functionality enabled by telemetry instrumentation, which would allow the utility to manage the power generated by this cluster. (See also "Virtual Power Plant").

Decoupling of Costs

Revenue decoupling is a way of separating revenue taken in to recover the fixed cost of delivery or distribution from the revenue taken in for electricity consumption, which is more variable.

It is expected that revenue decoupling would allow utilities to participate fully in energy efficiency measures designed by the Sustainable Energy Utility. These measures would enable customers to reduce their energy costs – the most significant portion of their electric bills.

Under revenue decoupling, customers would be charged a fixed amount for the cost of delivering their electricity. The charge would no longer vary month to month depending on the amount of electricity used.

Net Metering Impacts

Net metering is an electricity policy for consumers who own generally small renewable energy facilities (such as wind, solar power or home fuel cells). Under net metering, system owners receive retail credit for at least a portion of the electricity they generate. Net metering is generally a consumer-based renewable energy incentive.

A customer's net excess generation (NEG) in a given month is applied as a kilowatt-hour (kWh) credit to the customer's next bill. If a customer's generation exceeds consumption in one calendar year, the utility must pay the customer for that excess generation at the utility's wholesale rate for the prior 12-month period. Those customers of an investor-owned utility (IOU) that net meter, may, on or before the end of the calendar year, make a one-time election in writing to have their NEG carried forward indefinitely from month to month. If this option is chosen, they will surrender all their kWh credits if and when they terminate service with their utility [19].

If a customer-generator does not own a single bi-directional meter, then the utility must provide one free of charge. Systems over 10 kilowatts (kW) in capacity require a second meter to measure the output for the counting of renewable-energy credits (RECs). Customers accepting IOU incentive payments must surrender all renewable energy credits (RECs) for the next 20 years. Cooperative and municipal utilities are free to develop their own incentive programs at their discretion but they are not subject to the solar-specific requirements of the renewable portfolio standard (RPS). [19]

Capabilities that Affect Grid Operations

Virtual Power Plant (VPP)

A virtual power plant is a cluster of distributed generation installations, such as neighborhood rooftop solar photovoltaic, which can be run collectively by a central control entity. Please note that the term "Virtual Power Plant" is defined locally in this manner by Xcel Energy; some other utilities have used the term in reference to a Voltage Reduction program with Distribution Management.

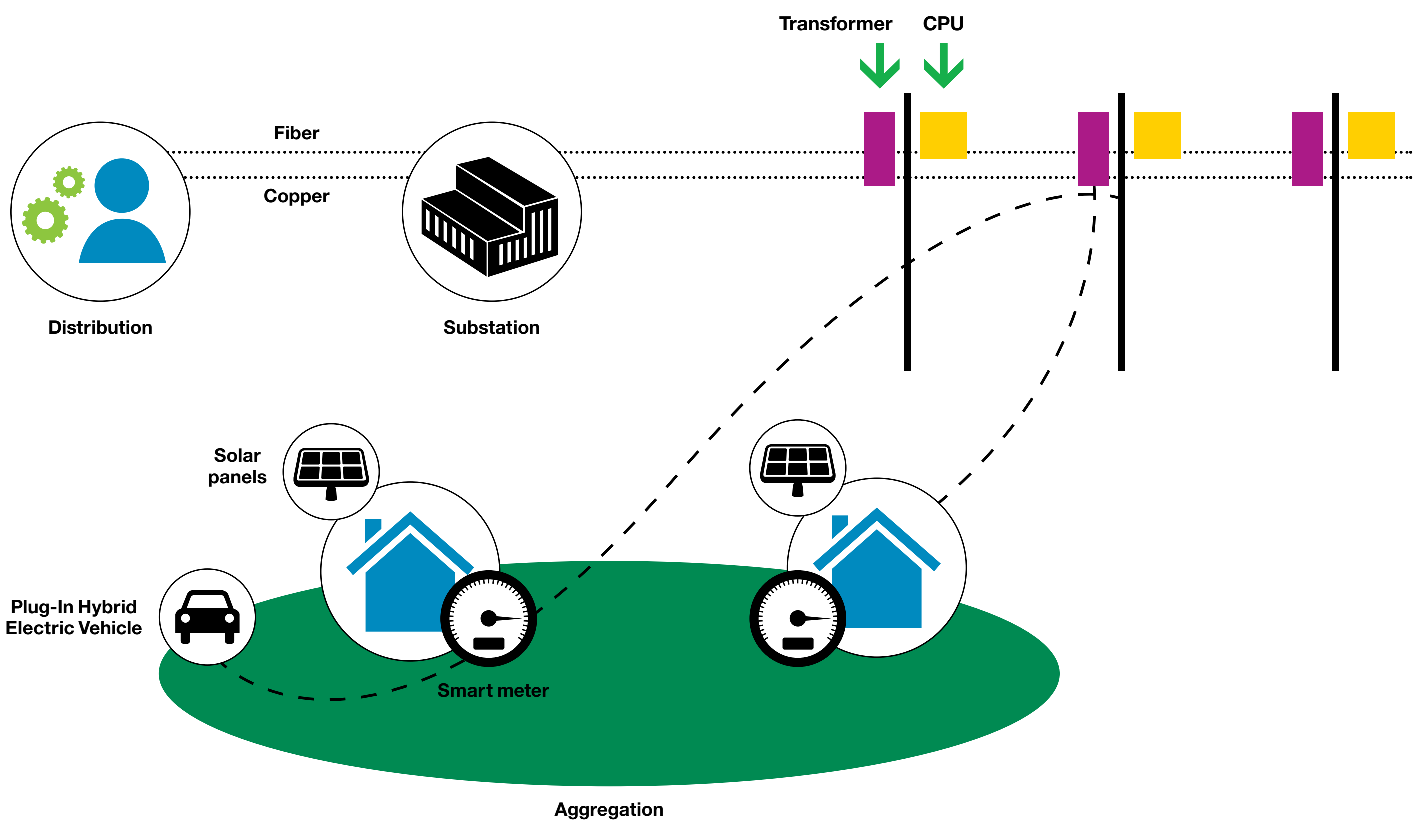

Figure 10
Local energy aggregation via Virtual Power Plant

The concerted operational mode delivers extra benefits such as the ability to deliver peak load electricity or load-following power at short notice. Other forms of virtual power plants are those where the utility can reduce the line voltage (within compliance limitations), thereby reducing the power required to serve the same load. Please refer to Figure 10.

Role of Provider of Last Resort
The Provider of Last Resort (POLR) serves as the default provider if a provider's services are no longer available, as in the case of intermittent renewables. The smart grid enables the utility to better balance power supply and demand across the grid so as to mitigate variability. This is another example of how smart grids support distributed generation.

Need for Open Standard for Communications
Electrical power is transmitted over high voltage transmission lines, distributed over medium voltage, and used inside buildings at lower voltages. Powerline communications (PLC) can be applied at each stage. Most PLC technologies limit themselves to one set of wires (for example, premises wiring), but some can cross between two levels (for example, both the distribution network and premises wiring). Typically the transformer prevents the signal being propagated, and so multiple PLC technologies are needed to form very large networks.

Power providers are also standardizing their internal and external communications including use of BPL technologies to provide direct links to power system components like transformers. In North America, another IEEE standard group is supervising these activities.

Unlike home users, power providers can consider widespread deployment of fiber optic cables for which mature devices (switches, repeaters) are available. These cables are immune to electromagnetic interference (EMI) and do not generate any EMI. Accordingly there is no single compelling reason, as there is in homes, to carry data on the existing power lines themselves, except in remote regions where fiber optic networks would not normally be deployed at all. Power network architectures with many transformers are more likely to be served using fiber.

Even if a home is using BPL it may not necessarily connect to the Internet using a BPL-based gateway (typically a smart meter), although this would have major advantages to both the consumer and provider. NIST and IEEE have considered whether requiring all smart meters to be fully functioning BPL gateways would accelerate demand side management and create a uniform market into which security, home control and other providers can sell.

The smart grid enables the integration, routing and backhaul of data on the utility private network and over transmission lines.

A2. Acknowledgements

We are grateful to the 60+ individuals who were gracious enough to meet with us over the course of the three weeks of the Boulder Smart Cities Challenge. It is only through their generosity that we have been able to gather enough material to create this document. We have tried to capture all of the names, but in some instances we may not have received a business card, and so apologize if we have inadvertently missed anyone.

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A3. Team Profile

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Brian is currently managing a department in IBM's Smarter Planet/Energy initiative, leading a grand challenge of smart grid simulation of regional US grid networks. He is helping to coordinate IBM's worldwide labs smart grid solutions. He also coordinates university research, working with external groups like SRC in smart grids as well as promoting power systems curriculum development around the world. Brian is an IBM master inventor with over 40 US and foreign patents pending, filed or issued. He holds three outstanding technical achievement awards and one corporate award and has co-edited one reference book, one book chapter and authored or co-authored over 50 papers. He is an active member of the IEEE and several standards groups P2030, 1809, 1547, 802.11, 802.15 and ECMA. He is a founding member and Chairman of the SRC's Energy Research Initiative.

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Brett Hansen is Director of IBM Tivoli Demand Systems Marketing. He has global responsibility for generating and managing the Tivoli pipeline. This responsibility includes defining Tivoli's go-to-market strategy and the successful application of this strategy with individual geographic organizations. He also heads the development and execution of the global demand program, including campaign design, asset development, global events, virtual marketing and the Tivoli Web. In addition, he is responsible for IBM business partner channel marketing. This includes supporting business partner pipeline creation, co-marketing activities, and joint marketing. Since joining IBM in 1999, he has held various strategy, business development and marketing positions. He has developed IBM's Service Provider program, marketing management for WebSphere offerings, and global e-business strategy.

Lisa Hopkins, Worldwide Lead, Government Industry – Buildings and Sustainable Cities (Bethesda, MD)

Lisa serves as the Global Leader for Buildings and Sustainable Cities in IBM Global Business Services (GBS). With cross-industry teams, she leads work that is focused on achieving smarter, sustainable built infrastructure to enable decisions as individuals, communities and cities. Some of Ms. Hopkins's specialties include but are not limited to the following: complex, cross-sector initiatives achieving high levels of internal and external client satisfaction; secure energy management, distributed generation; technical requirements/ SLA performance; performance metrics design; workforce development; end-to-end process, and organization change management. Lisa has 19 years of experience working with clients to design, implement, measure and manage solutions. Recent cities projects have focused on built infrastructure to serve as a roadmap for efficient operation of city assets, solutions in campus environments that provide functional benchmarks to manage assets and utility resources, provide web-based solution access, enterprise interaction and collaboration, visualization, and advanced analytics for improved decision-making.

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Geoff Jue is the Director, Americas Energy & Utilities Industry Leader, providing complex deal development and sales leadership for IBM's utility industry. Primary focus areas include integrated solutions around smart grid, customer service, energy efficiency, application and asset management and strategic outsourcing. Prior to this, he was the Client Unit Director for the E&U Industry, responsible for overall client satisfaction and sales attainment for IBM's utility clients in the Americas East. Geoff also served as the World Wide Solutions Offering Executive within IBM's Global Energy and Utilities Industry. Geoff brings to IBM 30 years of experience in the energy and utility industry. Before joining IBM, Geoff spent over 19 years working in regulated and unregulated utility companies, managing all aspects of utility and retail operations, customer care, and energy efficiency. He developed and implemented a first-of-a-kind business process outsourcing model for meter to cash within a major retail energy company.

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Lauren Laplante-Rottman is Global Energy & Utilities (E&U) Business Advisor for IBM's Global Business Services. In this role she is responsible for advising E&U consulting teams and developing and executing the solutions portfolio strategy for utility clients globally. Her focus is on smart grid, power generation and customer operations solutions. Prior to her current role, she was a managing consultant delivering smart grid solutions to utility clients across the U.S. Before this, Lauren was the energy analyst at FreeMarkets, now Ariba, where she was responsible for energy commodity auctions worldwide. Her 25 years of utility industry experience began as a metallurgical engineer with Public Service Electric and Gas Company. Her tenure at PSE&G spanned several operating areas concluding as a senior analyst in the rate counsel department. Assignments at PSE&G included serving as a stakeholder representative on the committee which shaped the PJM capacity market.

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Dejan has over twenty two years experience in business, engineering, software and information technology (IT). As a Senior Client Technical Architect for IBM, he is responsible for setting the technical software strategy at key IBM clients, and leading the software technical teams to achieve the business and technology goals for the client. Dejan has held this role at IBM since 2006, working in many industries including State Government, Energy & Utilities, Insurance, HealthCare Payer, Financial Services, Electronics, Industrial, Aerospace, Manufacturing, Media & Entertainment. He has covered clients including State of RI, State of MA, State of ME, Northeast Utilities, National Grid, General Electric/GE Energy, NBC Universal, United Technologies Corp, CIGNA, and Travelers Insurance. Dejan is an Open Group Master Certified IT Architect, Open Group Master Certified IT Specialist and a Certified Document Imaging Architect. He serves as a Board Member for IBM's IT Specialist Certification Board and is a sought after career mentor within IBM's specialist community.

A4. The Value of Smarter Energy – Making the Case for Orchestrating the Network

B. Meckley, "*The Value of Smarter Energy, Making the Case for Orchestrating the Network*" IBM Center for Applied Insights, May 2011

Introduction

For most of the past 100 years, the shape of the utility industry has remained fairly stable. It's been "business as usual." But today, new pressures and unprecedented changes are creating a mandate for wholesale transformation to business as *unusual*. Utilities have to cope with much more than the familiar issues of rising fossil fuel costs and aging infrastructures. There is a new marketplace environment and fresh challenges that are in the process of transforming the entire industry–and for which many are unprepared. In coming years, utilities will require much greater flexibility and responsiveness, and action is needed in the near term to position them for what is to come.

The energy value chain is evolving rapidly and becoming more complex. Its traditional, utility-focused structure is already fading, to be replaced with a more dynamic one. There are alternative sources of power in the form of renewables like wind and distributed generation that are fundamentally altering the nature of the network. The rhythm of the 24-hour load cycle will shift as plug-in electric vehicles become more widespread.[1] At the same time, consumers are starting to take a more active role in managing their energy consumption and they are looking to energy providers for help.

There are also threats from new, non-traditional (and unregulated) competitors that are piggybacking on the investments made by the industry. Microsoft, with its Hohm energy management services, is an example, as is Google with its investment in offshore wind energy. To compete, utilities need to think about new revenue streams and services which position them as a true partner, one that is motivated to help their customers achieve their goals as a means to business success.

Maintaining profitability and growth in this shifting landscape is a critical issue. Demand growth in developed markets is slowing[2] as energy efficiency initiatives start to produce results. In the U.S., for example, the growth in consumption in the first decade of the 21st century was less than a quarter of that in the period from 1980 to 1990. This energy conservation limits revenue growth and makes future investments more difficult to justify. Utilities are increasingly challenged to make better, smarter use of existing assets to generate financial return. The transformation from conventional utility networks to much more efficient, smarter grids has become a critical business imperative.

The industry, as a whole, understands that the network needs to be optimized and orchestrated, and that information and insight are essential contributors to this effort. To create a smarter energy value chain, it is necessary to gain a deeper understanding of customers, partners and the network itself. Energy providers need to see what's happening across the grid and even beyond the meter. This knowledge will allow the industry and consumers alike to make real-time adjustments and better decisions.

But how does one achieve this goal? Most utilities have already taken measures to improve their capabilities, yet still lack the degree of maturity required to make the most of those investments. What steps do they need to take next to achieve full transformation to smarter energy? What needs to be done now and in the near future to achieve success over the long term?

More importantly, are the investments necessary for the utility to rise to the next level truly worthwhile? What are the potential returns? Who are the beneficiaries? Customers and regulators are key stakeholders and utilities must demonstrate that investments will benefit not only themselves, but customers, too.

Utilities need to both understand the necessary transformational steps and quantify the gains that those initiatives can produce. Our research[3] suggests the potential for cost savings and capital expenditure deferral is considerable as compared to the status quo. Indeed, it can measure in the hundreds of millions of dollars, with significant ROI and payback comparable to other typical large infrastructure investments.

What's the overall potential for a utility?

Our detailed modeling[3] of an illustrative, vertically-integrated utility shows that a program of investment in smarter energy could yield:

- Total benefits: US$5.9 billion
- 15-year ROI: 225%
- Net present value savings: US$1.5 billion over 15 years
- Total investment: US$1.8 billion

Figures based on financial modeling[3] of utility with more than two million customers, assuming average operational maturity and investment in a full range of business capabilities.

The benefit of going beyond existing smart grid initiatives

Taking a holistic approach to grid optimization and orchestration produces the greatest benefit for both the utility and its customers. It enables active participation in the network by all parties, including the suppliers and distributors of power, and those who consume it.

The potential benefits of participation are highlighted by smarter energy examples like the successful Olympic Peninsula Project, part of the Pacific Northwest National Laboratory's GridWise initiative. During the demonstration project, utility customers had remotely controlled thermostats and other appliance controls installed in their homes. Preferences for convenience versus cost were captured via a web portal and used by the utility to adjust thermostats and control clothes dryers and water heating during winter peak periods. In exchange for reduced consumption and slightly cooler homes, customers and the utility avoided the high cost of peak power and bills were reduced. By leveraging information to coordinate demand response and empower consumers, the project yielded a 10 percent reduction in customer electric bills and a reduction in peak grid loads of 15 percent over the course of a year.[4] All parties benefited: consumers used less electricity, the utility was able to increase reliability and avoid interruptions, and local generators were able to better optimize power plant operations. This shows how utilities can take engagement and information to the next level – actions that support both company objectives and societal outcomes.

Many utilities are moving in the direction of smarter energy. Major investments have been and continue to be made in technologies such as smart meters, remote asset monitoring, demand response systems and information portals to instrument and interconnect the grid. These represent large investments and can produce significant returns. In Italy, for example, leading power company Enel installed more than 30 million smart meters at a total cost of €2.1 billion – and is recouping its investment at the rate of €500 million per year, largely through cost savings.[5] Enel's experience also shows how savings from smarter energy investments often extend beyond the initial scope and expectations. For example, in addition to reducing meter-reading costs, the new equipment helps to identify theft, places sensors on the grid that spot outages and provides data that can be used to assist in capacity planning.

Going beyond technology investments like these, however, can significantly enhance economic gain for all stakeholders. The ultimate goal is to create insight that drives orchestration of the network by its participants. Relatively small additional investments in information management, analysis and optimization create a unified grid that is far more capable and responsive – and at a lower cost than alternatives. This enables all stakeholders to contribute to more efficient and sustainable energy delivery while being better able to achieve their own goals.

The journey towards smarter energy

The path towards a dynamic, optimized and orchestrated utility network has clearly defined transformational steps. The journey begins with infrastructure improvements that lay the groundwork for grid transformation, then builds on those investments to maximize the use of information to create insight.

The foundational step is to **monitor and automate** the network. Automated control and real-time knowledge have existed for some time in the realm of generation and transmission, through established technologies such as SCADA. Investments in advanced monitoring, sensors and control devices extend these capabilities to the distribution network. This can give full, near-time visibility over all events and devices. This enables more effective management and provides the information needed to support more advanced capabilities, such as the ability to optimize the network.

Next, utilities build on the foundation of visibility by **connecting participants** to the utility – not only electrically, but also with two-way information flow. Investments in information exchange technologies such as data integration, alerts, portals and dashboards do much more than empower participants with information. They enable distributed generation, storage (for example, using electric vehicles to store energy) and the use of price signals to manage demand. Connecting all participants is a landmark event because it fundamentally changes the relationship of the utility with its customers and value chain partners. This can foster cooperative action beyond the traditional boundaries of the business. Engagement, education and empowerment are important; return on investment is maximized when stakeholder participation is achieved.

Even today, a lack of visibility into the state of the grid hampers many utilities. They are often unaware that a problem exists until a customer calls to report it. Drawing on information from across the value chain and leveraging it through such capabilities as advanced outage management gives the utility the ability to **sense and respond** in a timely way. For example, live data correlated across multiple sensors located throughout the network can trigger automated alerts about the exact nature and location of a fault. This alone can dramatically improve service thanks to faster recovery from outages.

The ability to proactively **analyze and optimize** the network by leveraging investments in information aggregation, automation and intelligent agents completes the journey. This leads to full orchestration, where each participant makes decisions based on relevant information and feedback from the actions of others. Consumers can potentially project usage and

The journey to smarter energy

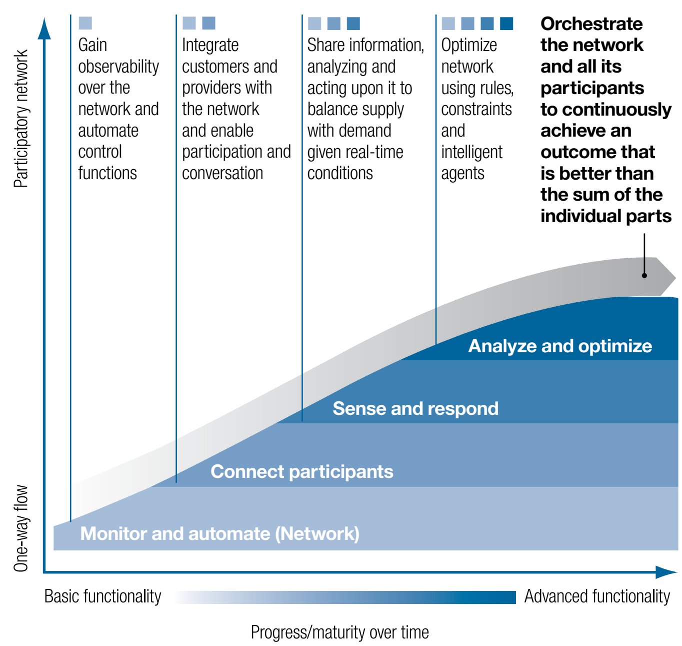


Figure 1 – The roadmap of development that leads to full network orchestration. With each subsequent step, the network becomes more participatory and transparent.

establish parameters to manage their consumption and utility bills. On the supply side, generators can determine the optimum level of production in real time, and utilities can configure the network to optimize performance. As more feedback is available, the entire network can be orchestrated to help ensure the best outcome for the system as a whole.

The roadmap shown in Figure 1 describes investments that build on one another to deliver a complementary series of enhanced capabilities. It is not a single, "one size fits all" approach; the details may vary according to the utility's particular circumstances, existing assets and initiatives, and priorities. It should be noted that achieving a smarter energy future is a process that takes time to come to fruition, which emphasizes the importance of action in the near term. Utilities that begin to transform today will be in an advantageous position in the coming decade, and should be better equipped to counter emerging competitive and market threats.

As shown in the model Figure 2, there is a high degree of synergy and added benefit to the utility as one progresses along the path.[3] The financial gains accelerate over time, with returns starting early in the journey. Monitoring and automation, for example, are mostly complete and already beginning to deliver tangible results by the end of the second year, assuming an eight-year course of investment in accordance with the roadmap.

The full scale of benefits, however, can be realized as the more advanced steps leverage the earlier capabilities. So, while investments can be made in a different sequence or in parallel, it is still important to address all of the steps.

How financial gains are realized

The discussion to this point has centered on investment steps and their resulting business capabilities. Making the economic case for investment, however, requires consideration of exactly how those capabilities yield quantifiable financial gain. How does gaining better control of the grid help the utility avoid capital investment, for example? What are the financial implications? How do customers realize additional gains? Our research and quantitative analysis that underlies this paper was undertaken specifically to help answer these questions.

Annual benefit at year 10 for an illustrative utility

More than two million customers

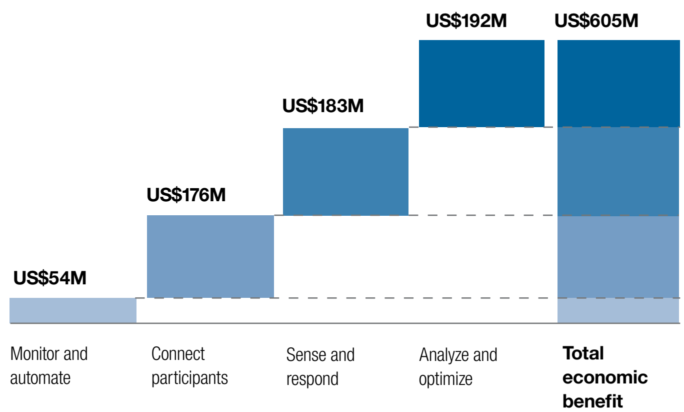


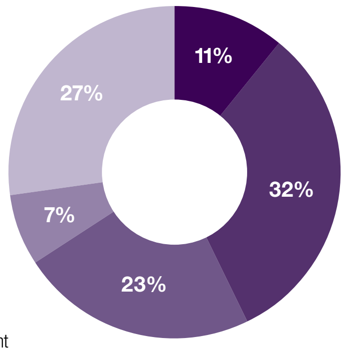
Figure 2 – While benefits accelerate with more advanced capabilities, early-step investments can produce significant gains of their own.

How we put a value on "smart"

The information and projections contained in this paper are based on research conducted by the IBM Center for Applied Insights among energy and utility industry leaders around the world. Case studies of 15 utilities were conducted to estimate potential benefits, addressing smart grid, transmission and distribution operations and regulatory policy. The team supplemented this primary research with data from more than 100 academic and industry studies and sources, combining all the input with their own experiences and perspectives.

The model for smarter energy investment that emerged from this research, along with the hypothetical value projections, is designed to help companies gauge their potential returns from their own, similar investments. The model can be scaled for different industry segments and corporate maturity profiles to produce individually tailored assessments and estimates directly applicable to your business.

Annual benefits* by area for an illustrative utility[3]



- **T&D O&M costs**
  Reducing T&D O&M costs for maintenance, metering, field operations, restoration and call center activities
- **T&D CapEx**
- **Generation CapEx**
  Reducing Generation and T&D capital investment through better asset management, voltage/VAR optimization, distribution automation and capacity forecasting
- **Energy Costs**
  Reduced energy cost by controling line losses and identifying theft and other commercial losses
- **Environmental**
  Reducing emissions through lower energy consumption and reduced line losses

*Note: The annual benefit at Year 10 (steady state) for this illustrative utility is US$605 million. Percentages rounded for clarity.

Figure 3– The breakdown of benefits for our illustrative utility with a typical full cou rse of investment .

As shown in Figure 3 there are several key value drivers for the energy provider. These drivers range from large-scale infrastructure spending, to costs associated with energy losses, to environmental concerns and day-to-day operational costs.

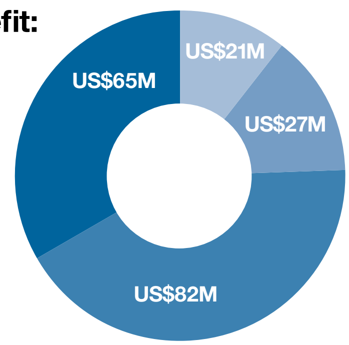
Naturally, gains for any given utility will vary considerably both in magnitude and how they are distributed among the value drivers. Also, results depend on such variables as existing capabilities, size and the presence of external factors like carbon-reduction incentives For this illustrative example, our modeling[3] shows that it is possible to achieve US$605 million in annual benefits following investments in a full range of capabilities as shown in the roadmap.

Transmission and distribution capital expenditure

Facing an impending need for network infrastructure investment, the illustrative utility is able to leverage enhanced information and better management to defer those expenditures for approximately five years. By proactively optimizing line voltage, managing demand , forecasting capacity and maintaining assets more effectively, the company can use its existing infrastructure to meet growth in customer needs

Annual estimated benefit: US$195 million[3]

32% of total benefits



Investment returns by capability:

- Monitor and automate
- Connect participants
- Sense and respond
- Analyze and optimize

For example, an investment in demand response allows the utility to make better use of infrastructure assets and extend their life.

Benefits could include:

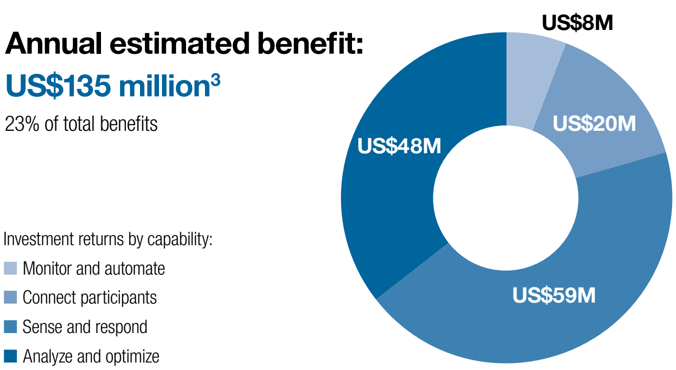
- A five percent reduction in peak demand through demand response and direct customer feedback[6].
- A 2.5 percent savings in capacity cost and a 15 percent reduction in equipment failure through better asset management and planning[7].
- A two percent reduction in peak load through voltage/VAR optimization. [8]

It is acknowledged that capital expenditures will eventually have to be made . The longer the investment can be deferred, the more the utility will save on capital carrying charges.

Generation capital expenditure

The illustrative utility also generates its own power. As with capital expenditures on transmission and distribution, it is possible to delay building new generation capacity by managing existing assets more effectively and fully understanding capacity requirements. In addition, the ability to incorporate alternative sources of power can have a major impact on the ability to defer generation capital expenditures.

Annual estimated benefit:
US$135 million[3]
23% of total benefits



Distributed generation and renewables help increase capacity and sustainability without building extremely costly new conventional plants. Successfully integrating these new sources, however, does require investments in connecting grid participants to manage energy exchange in real time.

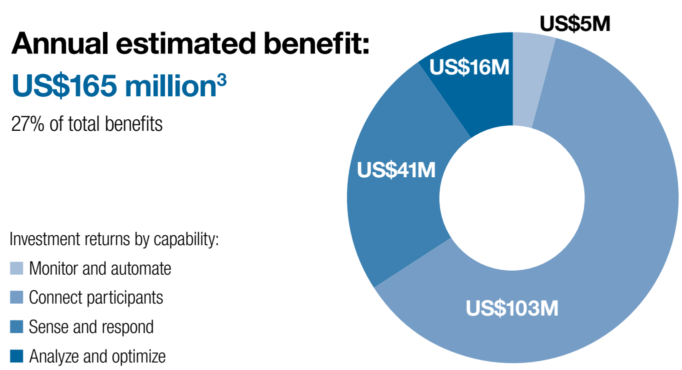
Benefits could include:

- A 6.5 percent reduction in peak demand through demand response and direct feedback.[7]
- A further two percent reduction in peak demand through voltage/VAR optimization.[8]

Environmental gains

There is a major opportunity for the illustrative utility, in the form of direct financial incentives, to reduce CO_2 emissions. But even where formal incentive programs or other carbon market merchanisms are not in effect, greenhouse gas emissions are of great interest to regulators and, increasingly, to customers and investors. This makes emissions reduction an important factor in investment planning.

Annual estimated benefit:
US$165 million[3]
27% of total benefits



The primary mode of achieving emission reduction is by promoting customer energy conservation. This emphasizes the importance of information sharing and investments in customer enablement such as information portals, consumption analytics and advanced metering. Initiatives that reduce line losses and create customer energy efficiency also lessen the need for additional generation with its associated emissions.

Benefits could include:

- A 0.2 percent reduction in supply needs through reduced line losses, with a further 0.8 percent through conservation voltage reduction.[9]
- A seven percent reduction in carbon emissions through efforts to promote energy efficiency.[9]

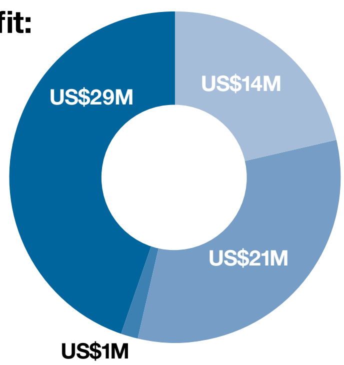
Transmission and distribution operations and maintenance

Compared to the returns on capital expenditure and environment, this value driver generates a relatively small portion of the overall gain. Nevertheless, it is still considerable, contributing US$65 million in the illustrative case. Its importance can be much greater. Any company that attributes much of its costs to activities like field operations, service restoration and customer service can achieve major gains in the course of making them more efficient.

The goal here is to control the scope and severity of outages and reduce the amount of physical intervention needed. For some operations that require field trips, the same outcome can be achieved remotely, and far less expensively, through automated outage management, advanced metering and similar investments.

Annual estimated benefit:
US$65 million[3]
11% of total benefits

Investment returns by capability:
- Monitor and automate
- Connect participants
- Sense and respond
- Analyze and optimize



Better management of outages, assets and distribution, along with advanced metering, could yield a broad range of benefits:
- A 10 percent reduction in restoration cost, through improved fault monitoring, outage management and self-healing grid capabilities.[10]
- A 10 percent reduction in outage call handling time through remote monitoring of conditions on the grid.[11]
- A four percent reduction in field trips through remote control of equipment.[8]
- A 90 percent reduction in the cost of connecting and reading meters, through remote meter operations.[12]
- A 10 percent reduction in maintenance costs, driven by improved, analytics-based asset management.[12]

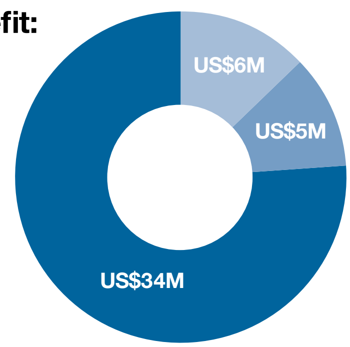
Energy costs

In some markets, theft and unaccounted-for power are significant contributors to the cost of energy for utilities. Here, a combination of visibility created by technology such as advanced metering and analytics can help spot unusual trends in usage. This is responsible for approximately half of the US$45 million estimated annual benefit. Reduced line losses through active control of line voltage – a capability dependent on investments in information connectivity, integration and analytics – accounts for the remainder.

Controlling the cost of energy requires making sense of the data on the network. That, in turn, requires a robust analytic and optimization capability.

Annual estimated benefit:
US$45 million[3]
7% of total benefits

Investment returns by capability:
- Monitor and automate
- Connect participants
- Analyze and optimize



The key is to understand where, when and how power is being lost, so the root causes can be addressed.

Benefits could include:
- A 0.2 percent reduction in supply needs through reduced line losses – which coincidentally also provide part of the environmental benefit cited earlier.[8]
- A 25 percent reduction in spending on power generated to compensate for commercial losses, including theft, lost meters and meter inaccuracy.[5]

Making the case for all stakeholders

The utility industry is unique, because customers and regulators are key stakeholders with a vested interest in the investments made by utilities. For this reason, it is necessary to make a good business case for audiences beyond the company and its investors.

The good news is that investment in smarter energy is beneficial for all concerned. The illustrative scenario shows that the financial benefit for customers is significantly greater than it is for the utility itself – more than 60 percent higher, as shown in Figure 4. Also notable is how early in the journey these benefits are realized.

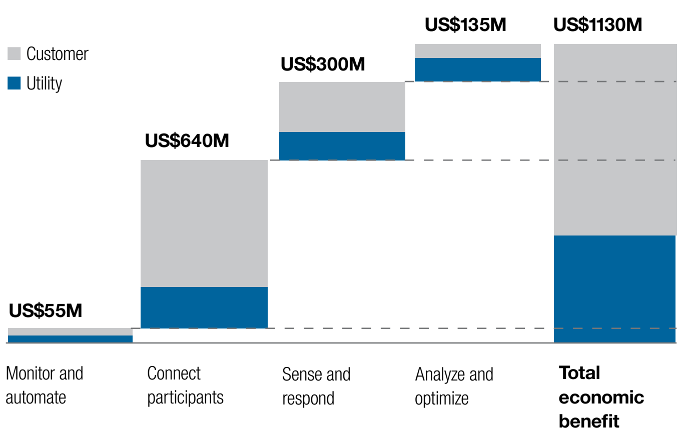
Empowered with information and programs that promote energy efficiency, customers can willingly change their behavior and reduce consumption – saving billions in the process. At the same time, customer satisfaction can increase due to more reliable service, faster recovery from outages and the potential for lower utility bills. There is also the intangible benefit of goodwill – the knowledge that customers are taking an active role in creating a sustainable energy future.

From the point of view of the utility itself, as well as investors concerned with cash flow, it is important to consider not only the direct benefits described above, but also the implications of *not* investing in smarter energy. Because of the long-term impact on rates, this too is of interest to consumers and regulators.

As shown in Figure 5, a traditional investment strategy is considerably more expensive over time. While expenditures for the first two years are higher with the new approach, the payoffs should be dramatic. As time passes and more advanced capabilities are put in place, the illustrative example indicates that savings of nearly US$2 billion each year can be achieved.

Looking deeper reveals why investment in smarter energy is so important. Staying with the tried-and-tested approach that focuses on major investments in infrastructure can accommodate growth and provide reliability if enough money is spent. However, the traditional approach can not only be far more expensive over time, it will likely fail to address uncertainty, risk and the growing need for flexibility.

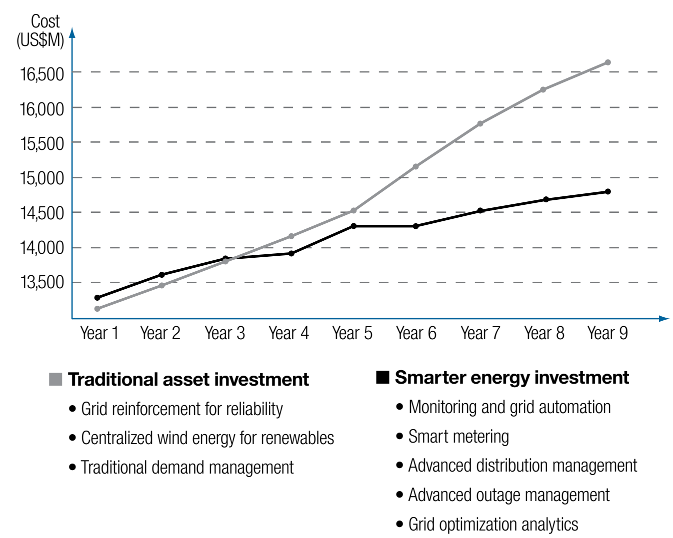
Additional potential customer benefits



Note: This is the annual benefit at Year 10 (steady state) for this illustrative utility and their customers

Figure 4 – The potential benefit to customers easily outstrips that obtained by the utility, with most of the benefit coming early.

Comparing investment approaches



Note: This is based on a comparison of the yearly costs for our illustrative utility with > 2 million customers

Figure 5 – Investment in smarter energy is initially more costly, but it positions the utility for significant savings over time.

With traditional investment, the utility remains fundamentally inflexible. It cannot engage easily with new entrants into the market, manage distributed energy sources that are becoming increasingly prevalent or facilitate greater customer participation. Taking a smarter approach to energy investment helps meet these new challenges head-on and positions the utility to survive today and thrive in the future.

Continue the journey

Our research has shown the rationale for investment in smarter energy and offers a view of the potential financial gains that can be achieved. It demonstrates the need to act and make the investments required to put your utility where it needs to be a decade from now. The path is not only clear, but achievable and could also prove to be profitable.

It is time to take the next step and make the case for your own stakeholders, laying out your specific investment strategy and why, compared to business as usual, it is the best way forward. The same research that lies behind this paper can be applied to your company, showing you in detail what is possible and what benefits the right course of investment can bring. If you would like to continue the conversation about how and where you can start, we invite you to contact the author.

About the author

Bridget Meckley is the IBM Center for Applied Insights Industry Champion for Energy and Utilities. She has 30 years of experience in the industry, leading transformation and business strategy engagements and providing operational guidance for system implementations with many electricity and gas utility clients. She brings this unique perspective to her current role of helping utilities explore the benefits of improving their operational capabilities and expanding their definition of value. She can be reached at bmeckley@us.ibm.com.

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[1] *Plug-In Hybrid Electric Vehicles and the Vermont Grid: A Scoping Analysis.* University of Vermont Transportation Center, September 2007.

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[3] All financial results cited in this paper are for an illustrative utility with over 2 million customers. The model used to arrive at these estimated figures is highly dynamic and customizable, and makes a number of assumptions about the sample company including overall maturity and investments made. The modelling methodology is based on extensive primary and secondary research including interviews and data from more than 100 industry and academic sources. Individual results for other company profiles will vary and the model can be tailored to accurately reflect individual circumstances. Figures shown have been rounded for clarity.

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[8] Schwartz, Lisa. "Is it smart if it's not clean? Part one: Strategies for utility distribution systems." *Regulatory Assistance Project Issueletter*, May 2010.

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[10] Tanskanen, Anna; Raussi, Tommi; Partanen, Jarmo and Lohjala, Juha. "Cost and benefit analysis for a distribution management system in electricity distribution networks." *International Journal of Energy Sector Management*, Vol. 4 No. 2, 2010.

[11] *Advanced Metering Infrastructure: NETL Modern Grid Strategy – Powering our 21st-Century Economy*. National Energy Technology Laboratory Office of Electricity Delivery and Energy Reliability, February 2008.

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A5. Concerns raised by Boulder Stakeholders

Concerns	Our observations
1. SmartGridCity is useless and should be removed	SmartGridCity has significant capabilities and benefits to the utility but consumer benefits have only been indirect to date. SGC can help enable Boulder's energy plan around reliability, renewables, energy efficiency, and rate stability.
2. The fiber portion is overkill	Fiber is a scalable robust communications backhaul infrastructure that provides capability to handle future utility needs privately, securely and reliably.
3. SmartGridCity is not prepared to incorporate more distributed generation into the grid	SmartGridCity can accommodate additional distributed generation on the system. Additional sensing and control in the home may be needed.
4. Xcel Energy does not support exceeding the State of Colorado's renewable standards	Xcel Energy is currently on track to exceed Colorado's plan for renewables and carbon reduction.
5. Consumers have no access to real time information	While participants do not currently have access to true real-time data, they do have access to 24 hour delayed information, which is validated and bill ready. This 24-hour old data is available on the My Account website. Xcel Energy has plans to make more raw meter data available sooner to participants.
6. There is no integration of electric vehicles into SmartGridCity	The utility is currently working with Nissan and Toyota on EV pilot projects.
7. SmartGridCity does not support localized generation	SmartGridCity was designed to accommodate additional distributed generation and renewables.

A6. Recommended Resources

IBM's thought leadership in Energy & Utilities is also a good source for utilities and consumers at the cutting edge of the smart grid.

Other energy related projects, materials and references can be found on IBM's Energy & Utilities Industry website at http://www.ibm.com/energy

Other energy and utilities related case studies can be found here:
http://www-01.ibm.com/software/success/cssdb.nsf/industryL2VW?OpenView&Count=10&RestrictToCategory=corp_EnergyUtilities&cty=en_us

IBM's Energy & Utility Industry webpage
http://www.ibm.com/energy

IBM's Institute for Business Value Papers
Switching Perspectives – creating new business models for a changing world of energy
http://www-935.ibm.com/services/us/gbs/bus/html/ibv-electric-utility-innovation.html

Lighting the Way – understanding the smart energy consumer
http://www-935.ibm.com/services/us/gbs/bus/html/gbs-emerging-energy-preferences.html

Plugging in the Consumer – innovating utility business models for the future
http://www-935.ibm.com/services/us/gbs/bus/pdf/ibv_g510-7872-00_plugging_in.pdf

A7. Illustrative Buildings Pilot: Promoting Energy Efficiency through Green Infrastructure Management

Energy Efficiency and Management

Sustainability is an ever-increasing and important metric. Building owners are investing in their own energy generation and storage capabilities. However, a balanced, consistent supply of energy will be important for any green infrastructure within the city. This includes renewables together with the management of, and accounting for, myriad alteration projects and green infrastructure improvements such as EV charging stations.

Smart grids encompass a mix of instrumentation, interconnectedness, and intelligence. They are key to ensuring we meet our environmental and energy security goals in a cost effective manner. Energy efficiency is viewed as the lowest impact and most cost-effective resource.

"If you cannot measure it, you cannot improve it."

—Lord Kelvin (William Thomson)

A Tool for Energy Efficiency Management of Small to Medium Scale Projects in Buildings

Management of alteration projects typically missed by other tools and services is essential to support the City's achievement of Climate Action Plan goals (aligned closely with U.S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) program) and to further the City's commitment to creating healthy, sustainable communities. At the same time, through these sustainable renovations and improvements, we have to reach a deeper level within communities to address the needs of business and residents. Careful thought, clarity and creativity in tackling the conceptual and technological development of energy efficiency measures, could provide the City with an enduring resource that communicates the principles of sustainable design in small projects. Its regulations-compliant application could lead to the innovation of sustainable workplaces. A Boulder-focused Sustainable Facilities Online Environment would place actionable tools in the hands of the City's buildings and facilities stakeholders. Knowledge related to sustainable building decision-making would be increased, skills sets built up to better assess building efficiency solutions, green lease standards, and current leasing standards. The ability of stakeholders to cope with new government regulations related to building efficiency would be improved.

Holistic, Integrated Planning

LEED and Energy Star certification are mandatory for high performance with a move to dramatically reduce energy consumption over the next 5 years through advanced lighting systems, smart metering, and the greening of building inventory. Detailed management of incremental improvements for buildings could help the City deliver a world class work environment for its own buildings and provide a way to account for additional gains achieved in commercial buildings within the city. The City could provide access to this supportive resource and tool to governmental agencies and private sector developers. This would help decision-making on sustainable building principles, materials, and systems for renovations, alterations, and general improvements. By utilizing a modular, flexible framework, this solution could adapt and expand as Boulder evolves.

In order to think critically about how this energy efficiency capability might be enhanced, an integrated design workshop is essential to brainstorm the full potential such a project requires. This process, a hallmark of high-quality sustainable projects, requires consistent interaction between all collaborators on the team. All current City needs should be examined, and future expansion anticipated.

Sustainable Choices

Outcomes for energy efficiency might include a checklist take away, to support the accessibility and adoption of sustainably designed small project repairs, renovations and improvements, based on ten common "module" spaces and their components. Content could consist of information and resources to support decision-making along sustainable building principles, specifications, construction, procurement, and management strategies that address, at a minimum, (i) energy efficiency and consumption; (ii) water efficiency and conservation; (iii) environmentally preferable purchasing; (iv) indoor environmental quality; (v) resource and waste management; (vi) operations and maintenance; (vii) occupant productivity; and (viii) employee and building management education.

Information and strategies provided would, at a minimum, help agencies implement the policies set out in the Energy Independence and Security Act of 2007 and Executive Order 13423, – Strengthening Federal Environmental, Energy, and Transportation Management and 13514, – Federal Leadership in Environmental, Energy and Economic Performance (LEEEP). They would incorporate sustainable practices and opportunities that comply with, or exceed the Guiding Principles set forth in Leadership in Energy and Environmental Design and the Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding (2006), while enhancing skill sets to assess lease submittals and architect and engineering (A/E) design team deliverables.

Selected products and resources would promote the use of energy efficient and environmentally preferable materials and systems, including Energy Star-rated and Electronic Product Environmental Assessment Tool (EPEAT)-registered products. As an additional resource, users would be able to review and rate products, allowing one user to learn from another's experience.

Technical Aspects for the Proposed Pilot

- **Market Efficiency** – The optimized resource management of individual and/or multiple organizations' distributed resources, energy storage systems and controllable load, to achieve economic value point. Each organization's business and environmental objectives would be met while achieving reliability.
- **Tenant Experience** – The inhabitants of a building play a critical role in the effectiveness of energy efficiency programs. First, the implementation of energy efficiency and demand management must be a satisfactory experience, so that tenants can live and work effectively. Second, tenants – properly engaged and motivated – represent an important point of control over energy demand.
- **Use of The Sustainable Facilities Tool** – such as the one created by the US General Services Administration Office of High Performance Green Buildings. This is a one-stop online resource, supporting decision-making on sustainable building principles, materials and systems. Using the targeted Sustainable Facilities Tool, project personnel can identify and prioritize cost-effective, sustainable strategies for small schemes. Users can understand and select environmentally preferable solutions and designs for renovations, alterations and leases.
  http://www.gsa.gov/portal/content/231801
- **PHEV infrastructure provision and management** – include this as part of the City's sustainability efforts. Look at EV pilots currently in progress with NREL and target broader implementation within the city and include renewable energy or distributed generation as local sources.
- **Open, Scalable and Secure Infrastructure for broad-based deployment**.

Business Benefits

- More cost saving opportunities throughout the day for building owners with optimized demand shifting and shedding.
- Put in place and managed specifically for them, communities of small businesses working together could profit from demand shifting and shedding through a combined supply mix of energy sources whether traditional or renewable.
- Better experience for building occupants as the demand response of the building becomes smooth and predictable
- Better system reliability for the market operator by turning unpredictable distributed resources into an aggregated set of predictable and price-sensitive resources.
- Gradual introduction of EV into the transportation modes within Boulder would be supported. This might be done through the provision of EV charging stations at local shopping centers powered with sustainable power sources. Charging could be free to shoppers, promoting the use of EVs within the city, and the use of that shopping center.

Core Value Drivers

The City of Boulder should start with a subset of its portfolio of buildings and small businesses to demonstrate these concepts:

- Open architecture and standards
- Building the system and data architectures that enable "inter-connectivity", interoperability and remote control
- Automated energy, water management and carbon analytics,
- Integrate renewable sources of energy
- Interact with the Grid to allow for demand side control – (See NIST and inter-operability activities, Domain Expert Working Groups (DEWGs), DoE GridWise Architecture Council for a large source of information)
- Interact with Distributed Energy Resources – The capability to provide energy system ancillary services promises to deliver more effective energy utilization
- Interact with PHEV Retrofit existing buildings with PHEV charging stations that use local sustainable energy.

Outcome Measurements for Sustainability

While implementing smart meters, integrating with demand response pricing systems and installing renewable power generation equipment in facilities are all critical elements of a smart building, it is vital for the City of Boulder to develop a clear and concise methodology for measuring success of the initiative from the onset.

Energy efficient buildings and utilization aware tenants. As an example, one approach would be to enlist a set of building tenants who are willing to let their consumption data be analyzed anonymously to record consumption patterns and establish ways and means of improving energy efficiency. They could also be given the option to compare their utilization against the aggregate utilization across a larger population.

Energy Intensity could be one of the example metrics. This is defined as the amount of energy used to produce a given level of output or activity. Though it is relatively easy to extrapolate the energy used from energy bills, an intelligent building could help you calculate whether that energy was used wisely or efficiently. Service level metrics could combine with the ability for tenants to have a measure of control. The key is to create metrics and analytical techniques that allow an organization to compare metrics effectively from building to building, and highlight the key drivers behind differences in energy intensity metrics from facility to facility. This is just illustrative of the many metrics available.

Other ideas – to build on this further could include the pilot: Public Cap and Trade – An open marketplace that would allow carbon cap and trade by customer or by building. This could be a proof of concept in the form of a game. A public marketplace could be enabled with virtual carbon credits that people can trade for and against their various activities. It is hoped that analysis of trading patterns would yield insights into the impact of people's activities on their carbon footprint and could be leveraged to encourage a sustainability-aware culture and pattern of consumption.

A8. Smart Grid Project Examples

MVV Energie AG – Model City Mannheim (MoMa)

Business challenge

In the City of Mannheim, a major German municipality, local utility provider MVV Energie AG is leading a consortium of companies and scientific institutes to establish a power management solution that would increase control over energy usage. Ideally, this integrated power management framework would accommodate multiple energy sources, including that produced by "prosumers" – consumers with the local means (e.g., solar paneling) to produce more energy than they consumed.

Solution

MVV Energie teamed with IBM Global Business Services and others to create a virtual marketplace that provides energy companies and customers with real-time energy generation, consumption and availability data. Users can employ this solution, which leverages IBM WebSphere® MQ Telemetry Transport software, to monitor local energy reserves and view current pricing for outside energy sources.

Benefits

- More sources of energy for customers to choose from – including renewable and local sources
- Lower cost and more efficient power generation through reductions in peak energy consumption; average customer energy cost reductions of 5 percent
- Reduced transmission loss through use of local distribution sources; stronger competitive differentiation.

"We see the solution as an enabler of smart grid services, a virtual marketplace where all the key elements needed to build a smart grid can be traded."

—Dr. Britta Buchholz Head of Grid and Plant Planning, MVV Energie AG

Hildebrand solves a Key Problem in Smart Metering Research with IBM Informix Technologies

The Need

As technology consultants on the Digital Environment Home Energy Management System (DEHEMS) project, the Hildebrand team was asked by the UK government to find a way to scale up its energy monitoring solution and enable it to monitor three million homes.

The Solution

Working with the software laboratory at IBM Hursley, Hildebrand created a solution based on IBM Informix technologies that has the potential to collect, store and analyse detailed energy usage information from homes in real-time. Sensors attached to a home's electricity supply transmit readings over a wireless network to a broadband hub. These readings are then sent to the central DEHEMS database. Users can access an online dashboard that displays their electricity usage and performs analytics.

What Makes it Smarter

- Enables real-time analysis of electricity usage for households or individual appliances, helping people make better decisions about energy efficiency
- Can collect, store and analyse up to 50,000 data points per second – demonstrating scalability to three million homes and beyond
- Delivers high performance on low-cost hardware by leveraging unique time-series data management technologies.

"With help from the IBM Hursley Innovation Centre and Lab, we quickly found that Informix TimeSeries could deliver spectacular results… You don't need to understand the technical details – the point is that suddenly, energy monitoring for three million homes or more became a practical proposition."

—Clive Eisen, Chief Technical Officer, Hildebrand

Oxxio Mdetering "Smart" Meteing improves Bottom Line – and Customer Service

Business Challenge

Though it had quickly grown into the Netherlands' largest independent energy supplier, Oxxio was looking for new innovative services that could initiate the next step of further growth and improved customer service. It wanted to find an innovative way to become independent of the distribution companies for the information it used to generate its customers' bills. Oxxio decided to enter the electricity metering business while maintaining its "lean and mean" cost structure.

Solution

Oxxio engaged IBM Global Business Services to create a new subsidiary business unit, and then outsourced the infrastructure-management and operation of the company to IBM. Oxxio Metering now uses a customized Automated Meter Management (AMM) solution developed by ENEL, an Italian energy company. IBM designed a unique wireless data communication module that gathers data from the "smart" meters and sends it directly to Oxxio's central control facility. Oxxio also pushes the envelope with its first-of-a-kind integration of electric and gas metering data into a self-service solution that allows customers to monitor their electricity and gas consumption.

Benefits

- Reduction in overall "meter-to-cash" costs by 50 percent through elimination of errors and late or inaccurate billing
- Advanced features like load profiling provide competitive differentiation, increase customer retention and promote conservation.

"Our experience reaffirms our belief that IBM and ENEL are at the forefront of smart energy metering. We see our decision to work with them as a sign of our commitment to giving our customers the best possible value."

—Erik de Heus, CEO, Oxxio

DONG Energy Making the most of the Intelligent Electrical Grid

Business Challenge

DONG Energy is Denmark's largest energy company. Increasing marketplace and regulatory demands along with a need for future infrastructure reinvestment drove Danish utility company DONG Energy to manage and utilize its electrical distribution network better in order to respond to outages faster and more efficiently.

Solution

DONG Energy has teamed with IBM to implement an Intelligent Utility Network (IUN), installing remote monitoring and control devices that give the company an unprecedented amount of information about the current state of the grid. The new solution also involves extensive analysis of the data provided by the remote devices, as well as reengineering of DONG Energy's business processes. IBM designed its service-oriented architecture (SOA) and IT infrastructure to accomodate the new processes. SOA makes IT processes far more flexible and scalable, improving DONG Energy's responsiveness.

Benefits

- Potential to reduce outage minutes by 25-50 percent
- Fault search time reduced by one-third
- Estimated capital savings on planned grid reinforcements of up to 90 percent, when fully implemented.

"It turns out that the real key isn't the fact that we've got visibility into the grid, though that was our initial goal. It's that we now have information available on grid performance that we didn't have before. We can do a lot with that information."

—Peter Vinter, power grid specialist, DONG Energy

Pacific Northwest National Laboratory – Aiming to Empower Utility Customers

Business Challenge

As part of the U.S. Department of Energy's GridWise® Program, the Pacific Northwest National Laboratory (PNNL) wanted an innovative way to keep the electrical grid healthy in times of stress by managing electrical demand through a combination of intelligent technology and financial incentives.

Solution

PNNL set up two parallel studies. In one, the lab teamed with IBM to create a virtual marketplace that allowed consumers to trade flexibility in usage for lower costs. Intelligent devices (such as thermostats) in consumers' homes were tied to the PNNL system, which automatically controlled power consumption in near-real time based on pricing signals and customer preference. The second study tested "smart" appliances that could sense and respond to stress on the grid by temporarily curtailing electricity use.

Benefits

- 50 percent reduction in short-term peak electricity distribution loads, helping to avoid power restrictions and cascading blackouts
- 15 percent decrease in overall peak loads in the course of one year
- Consumers saved an average of 10 percent on their electricity bills
- US$70 billion projected reduction in infrastructure spending over 20 years through better management of existing resources.

"We're finding that people are actually curtailing their use and saving energy simply because they have greater control."

—Don Hammerstrom, project manager, Pacific Northwest Gridwise Demonstration Projects

Smarter Metering Project – Dubuque, Iowa

- Dubuque wishes to conserve water and avoid wastage. Conserving water can also help consumers lower bills that are set to go up due to new, more accurate meters.
- IBM Research working with City, Water utility and 250 pilot residences and providing platform for all stakeholders to process and analyze consumption.
- Strategy is to leverage information, alerts and insights to encourage change in behavior resulting in conservation and fixing of leaks
- Present analysis in a simple, user-friendly form, game-based approach.

CentrePoint Energy – Breaking New Ground in Grid Reliability through the Power of Automation

The Need

Like the rest of the electric transmission and distribution industry, CenterPoint Energy needs to deliver power more efficiently and reliably in the face of growing consumer expectations, environmental concerns and increasing costs. The company also sees the opportunity to break new ground in grid management practices.

The Solution

Subject to approval by its regulators, CenterPoint Energy plans to leverage a mix of leading edge communication technologies, smart meters and first-of-a-kind process innovations to create one of the industry's first intelligent utility networks.

What Makes it Smarter

- Improved ability to leverage information, make the grid more reliable and operations more efficient
- Reduction in the frequency and duration of power through proactive management and automated response
- Near real-time electric use data provided by smart meters to the utility and to the consumer.

"We expect that the Intelligent Grid will improve electric power line grid planning, operations, and maintenance, enabling us to deliver power more efficiently. We also expect the technology to contribute to fewer and shorter outages."

—Tom Standish, Group President, Regulated Operations, CenterPoint Energy

Ausgrid – Smart Network Monitoring Prevents Power Outages, Improves Services and Lowers Costs

Business Challenge

Energy Australia wanted to improve its ability to pinpoint faults by location and type and to replace manual network monitoring procedures with a real time "digitally aware" solution that would gather network data directly into its network operations center (NOC).

Solution

Energy Australia engaged IBM Global Business Services to design, build and integrate the IT Systems to create an electricity network distribution monitoring and control system. Energy Australia deployed the sensing devices in 12,000 of the company's distribution sub-stations across the electricity network to gather and bring data back into the NOC, enabling Energy Australia to monitor the status and health of its electrical distribution network in real time.

Benefits

- Improves asset and power management, enabling Energy Australia to deliver energy more efficiently and reliably
- Energy Australia can identify faults in real time, speeding up fault restoration times, and identify assets requiring preventative maintenance to prevent faults before they happen
- The system will allow new environmental solutions – such as renewable energy and distributed generation – to be integrated into the electricity network.

"This project will help us stay at the forefront of the global intelligent network transformation."

—George Maltabarow, Managing Director, Energy Australia

Oncor – IBM is Systems Integrator for Smart Metering Deployment

What is Smart

Oncor's advanced metering systems deployment is reporting 15-minute interval, billable-quality data to the Texas market, in one of the most comprehensive and largest deployments of smart grid technologies in the nation and is scheduled to replace 3.4 million standard meters with advanced meter systems by 2012.

Solution

- IBM is providing expertise in smart metering and systems integration along with its understanding of large meter data management, business analytics, and security solutions.
- IBM's Solution Architecture for Energy and Utilities (SAFE) is a software framework. Products such as Data Power, Maximo, Tivoli Identity Manager, Tivoli Compliance Manager, to name a few, will enhance the security and reliability of the information technology solution.

In Oncor's Smart Texas(SM) initiative, IBM is responsible for integrating the complex systems supporting Oncor's advanced meter system deployment.

"Achieving the important step of reporting 15-minute interval, billable-quality data to the Texas market wouldn't have been possible without IBM's participation."

—Mark Carpenter, VP & CIO, Oncor

Energie Baden-Wurttemberg AG (EnBW) Influencing Energy Use Behaviour by Real-Time Pricing

Business Challenge

Whereas industrial energy customers get tailored energy tariffs according to their need, residential customers could not take advantage of flexible energy prices. EnBW wanted to be the first utility company in Germany to offer advanced energy service to households. A time-of-use price will influence the behavior of the clients to shift energy use from high peak time to low time periods. EnBW needed to set up a flexible solution to define, publish, communicate and bill real-time pricing. This included the development and intergration of smart devices like displays in the living-room to publish prices and to set up an automated meter infrastructure to collect consumption data.

Solution

To solve these complex challenges, EnBW joined forces with IBM Global Business Services to design and realize a solution for a first-of-a-kind pilot project. Using the Global Business Services support, the EnBW and IBM team developed a display called the Power Price Signal Device that can be conveniently mounted anywhere in the home. The actual energy prices are displayed on the device, reflecting peak and low price periods. A customer-specific application generates the individual current prices for each day, depending on the corresponding EEX (energy exchange) day-ahead prices and a monthly report to show the individual energy consumption and monthly consumption prices. Smart electronic household meters from EnBW continuously collect consumption data that is transmitted, processed in the backend systems and used for billing.

Benefits

EnBW predicts that the solution, when implemented in the pilot 2008, will give a full view on real-time pricing potential. This includes the behavior of clients, structure of tariffs and field-proven technical infrastructure to change "on demand" energy prices for residential customers.

"The Power Price Signal Device display will be of significant benefit to our customers, who will be given an effective, innovative method by which to control their monthly utility bills. It can even tell them when it is least expensive to use high energy consumption appliances, saving our customers money and increasing our company's energy efficiency."

—Hellmuth Frey, Project Manager EnBW

Energie Baden-Württemberg – Laying the Groundwork for "Smarter" Energy Consumption and Generation

What's Smart

Energy customer display showing energy pricing (employs a "traffic light" motif, in which the "best" (that is, lowest priced) time intervals are displayed with a green background, the most expensive with a red background, and intermediate or "normal" prices in yellow.

Smarter Outcomes

- Lower cost and more efficient power generation through reductions in peak energy consumption
- Improved ability to absorb alternative energy sources into the power grid
- Lower energy costs for the customer.

Enemalta and Water Services Corporations – Building a Smarter Energy and Water System

Business Challenge

On the island nation of Malta, electricity is generated entirely by imported fossil fuel, and electrically powered desalination plants provide over half its water supply. Meanwhile, rising sea levels threaten Malta's underground freshwater source. This complex series of challenges requires immediate attention to ensure that the country delivers affordable, secure energy while protecting the environment. In addition, to meet this challenge, both Enemalta and Water Services Corporations are undergoing an internal transformation process geared towards increased efficiency.

Solution

The Maltese national power and water utilities are partnering with IBM to help their country become the first in the world to build a nationwide smart grid and a fully integrated electricity and water system. 250,000 interactive meters will monitor electricity usage in real time, set variable rates, and reward customers who consume less energy and water. Furthermore, in assisting in the transformation of both utilities, IBM is entrusted to implement a customer relationship management (CRM) and Billing solution, as well as Enterprise Resource Planning (ERP) core modules, while a new Web portal will be set up for both utilities to interact better with their end customers.

Benefits

- Data from intelligent meters can be analyzed to help lower costs, adopt efficient and sustainable consumption patterns and cut greenhouse gas emissions
- By addressing water and power issues as a system citizens can make smarter decisions about how and when they use power.

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