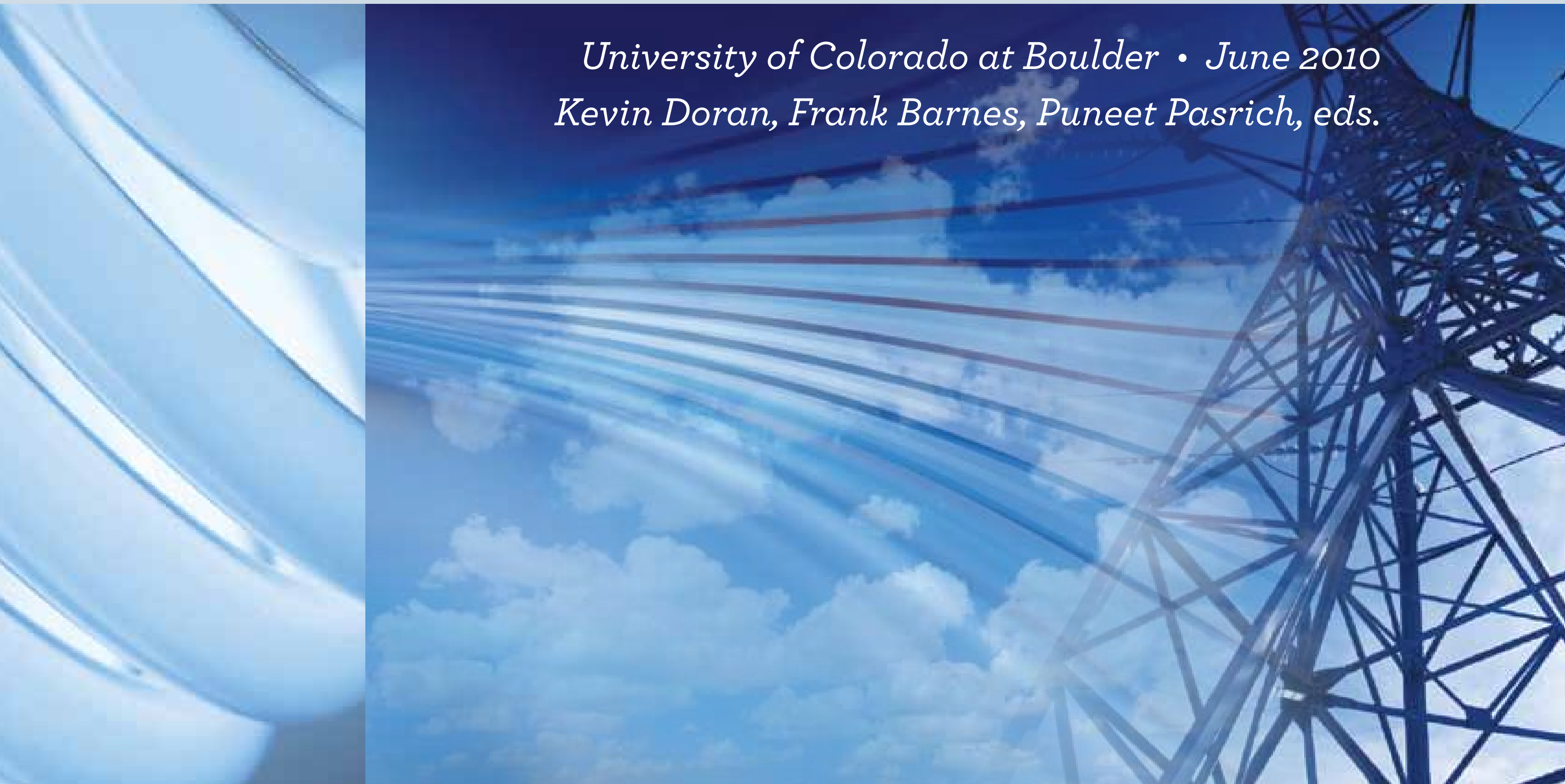
SMART GRID DEPLOYMENT IN COLORADO:

CHALLENGES AND OPPORTUNITIES



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Kevin Doran, Frank Barnes, Puneet Pasrich, eds.

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TABLE OF CONTENTS

INTRODUCTION

The U.S. electric grid—a staggeringly complex network of interconnected electric systems—is poised to undergo a major physical, operational and conceptual transformation with far reaching implications. By incorporating literally millions of new intelligent components into the electric grid that deploy advanced two-way communication networks with interoperable and open protocols, the "smart grid" heralds a fundamental change in the electricity paradigm that has prevailed for more than a century.

The modernization of our nation's electrical grid has the potential to make a significant impact on the way Americans use and conserve energy. Simply put, the smart grid is an upgrade of our century-old power grid to a new system which incorporates innovative technologies to enable the grid to deliver power in more optimal ways.[1] Unlike the current grid, a fully-functioning smart grid will deliver electricity from suppliers to consumers using two-way digital technology and utilize an intelligent monitoring system to keep track of all electricity flowing in the system.[2]

The purposes of grid modernization are to ensure grid reliability, maintain affordability by giving consumers more control, resist both physical and cyber attacks, reinforce global competitiveness, accommodate renewable energy sources, reduce the nation's carbon footprint, and introduce ground-breaking advancements into the electric industry.[3]

The smart grid will incorporate a variety of technologies and tools, allowing the grid to work far more efficiently. The U.S. Department of Energy has listed five fundamental technologies that will drive the smart grid; these technologies include:

- Integrated communications, connecting components to open architecture for real-time information and control, allowing every part of the grid to both 'talk' and 'listen.'
- Sensing and measurement technologies, to support faster and more accurate response, such as remote monitoring, time-of-use pricing and demand-side management.
- Advanced components, to apply the latest research in superconductivity, storage, power electronics and diagnostics
- Advanced control methods, to monitor essential components, enabling rapid diagnosis and precise solutions appropriate to any event.
- Improved interfaces and decision support, to amplify human decision-making, transforming grid operators and managers into visionaries when it comes to seeing into their systems.[4]

Although grid modernization is simple in theory, smart grid deployment is a complex process. Thus, the success of the smart grid will require a comprehensive, multi-disciplinary understanding of the various industries and players whose actions must be coordinated to ensure its successful, efficient, and safe operation. The purpose of this White Paper is to provide the Colorado Smart Grid Task Force with a comprehensive survey of important smart grid topics, as well as probable and potential issues related to the deployment of the smart grid. The Paper consists of 13 chapters; each chapter endeavors to provide essential background information, key issues, and recommendations.

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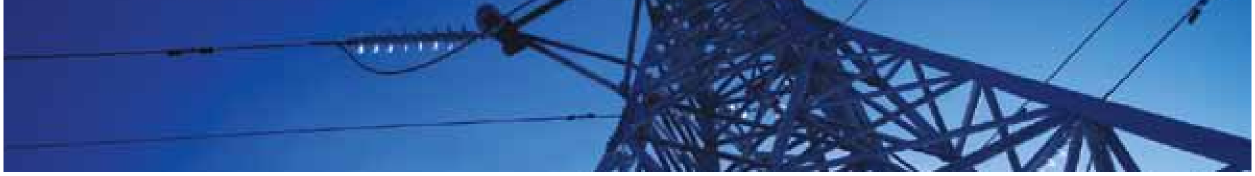
[1] U.S. Department of Energy, "The Smart Grid: An Introduction," ***available at*** http://www.oe.energy.gov/DocumentsandMedia/DOE_SG_Book_Single_Pages(1).pdf.

[2] *Id.*

[3] *Id.*

[4] *Id.*

Three different reference styles exist throughout this White Paper. The contributing authors used their authorial discretion to select the reference style that best suited the nature of their chapter. The three styles include: footnotes, parenthetical citations, and superscript numbers which correlate to the numbered references that appear at the end of this Paper.



CONSOLIDATED RECOMMENDATIONS[1]

Chapter 2. SMART GRID ARCHITECTURE AND AN OVERVIEW OF ENERGY STORAGE, GRID STABILITY, AND INTEROPERABILITY

Architecture

Distributed Generation (DG) is an approach that employs small-scale technologies to produce electricity close to the end users of power. Today's DG technologies often consist of renewable generators (i.e. solar PV, wind turbines, microturbines), and offer a number of potential benefits. In many cases, distributed generators can provide lower-cost electricity and higher power reliability and security with fewer environmental consequences than traditional bulk power generators. DG may provide the consumer with greater reliability, adequate power quality, and the possibility to participate in competitive electric power markets. DG also has the potential to mitigate overloaded transmission lines, control price fluctuations, strengthen energy security, and provide greater stability to the electricity grid. The primary applications for DG are:

- *Combined heat and power (cogeneration) plants* increase the efficiency of on-site electricity generation by using the "waste heat" for existing thermal loads. These plants use a gas turbine or Stirling engine exhaust for a heating process. Many manufacturing facilities utilize cogeneration plants to supply electricity and heat to their electrical and thermal loads, respectively. Energy efficiency improvements of 20% are possible by capturing and harnessing this otherwise lost thermal energy.
- *Premium power production* reduces frequency variations, voltage transients, surges, dips, or other disruptions.
- *Back-up power* is used in the event of an outage, as a back-up to the electric grid.
- *Peak shaving* is the use of DG during times when electric use and demand charges are high.
- *Low-cost energy* is the use of distributed energy sources as primary power that is less expensive to produce locally than it is to purchase from electric utilities.

DC Microgrids are another potential solution to reduce electric losses and to support distributed generation. The conventional electrical system in place today powers our electrical devices by AC mains. But as renewable technologies such as solar PV become more prevalent at a household level, DC microgrids could be a cheaper and more efficient alternative. PV cells and many small scale renewables generate low voltage DC power. Often these generators require power invertors with transformer efficiencies of about 92% to supply power to AC circuits, though the power may ultimately be delivered to a DC device.

- A possible solution is to install a DC circuit network linking DC devices to DC power supplies.
- Such networks have not yet proliferated because of the higher costs to install a parallel set of circuits in buildings which are served by DC power. Also, at the transmissions level, higher electrical losses are associated with transmitting a fixed amount of power as low voltage DC rather than high voltage AC.
- The proliferation of low power electronic devices and the potential for LEDs to reduce electrical loads by up to a factor of 10 for indoor and outdoor lighting makes the use of localized DC microgrids practical.

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[1] Chapter 1 provides an overview and does not contain recommendations.

Renewable Energy Integration is the path towards sustainability but the present electric grid is not suitably equipped to handle the increased use of renewable-based electrical generation. A few solutions are recommended to tackle those issues include:

- Dynamic scheduling of dispatchable generation.
- Consolidation of balancing areas.
- New operational practices and economic curtailments.
- Better use of flexible energy storage, including dispatchable hydro and pumped storage.
- Plug-in hybrid electric vehicles (PHEV) with smart-charge controllers that can manage power demand and supply to the grid.
- Price-responsive load balancing, including Demand-Side Management (DSM) and Demand Response (DR).
- Integration of wind forecasting into the control room.

Storage

- Storage should be considered as an alternative to gas-fired generators as a means of coping with the variability of wind and solar energy. It may be both the low-cost solution as well as the most flexible tool to accelerate a large amount of renewable energy generation in Colorado.
- Potential sites for energy storage should be considered as part of the state-wide plans for the development of the smart grid.

Grid Stability

- Voltage control must be achieved with both conventional and renewable energy sources on the grid. Traditional grids use capacitors and synchronous condensers to maintain voltage control. The grid was designed for conventional sources with both their real and reactive power generation. To get solar energy sources on the AC grid, DC-to-AC inverters must be used. DC-to-AC current-controlled inverters have useful properties which allow them to operate near zero power factor to produce reactive power. Such inverters are advantageous because they can both supply or absorb reactive power only and do not require real power. In addition, they can be installed at strategic points within the distribution system. A major advantage is that these novel reactive power inverters do not participate in resonances, as capacitors do.
- Steady-state and transient stability is based on load-frequency and voltage control through the deployment of short and long-term energy storage facilities, demand-side management, load balancing networks, and harmonic power eliminators, which can compensate for the intermittency of renewable energy sources.
- Reliability can be augmented by two-way, digital, automatic communication/control between dispatch centers, generation facilities, and dispersed loads.
- Security of communication/control must be ensured to an acceptable level of risk and is likely to require encryption.

Interoperability

- Establish common ground rules of interoperability that utilities and smart grid technology manufacturers must follow.
- Interoperability among disparate computer systems can only be achieved through the use of internationally-recognized communication and interface standards. The National Institute of Standards and Technology, in

consultation with industry and other stakeholders, is currently creating cyber-security standards.

- Develop a smart meter operational framework to enable all smart meters to operate in harmony. In other words, develop standards for interoperability between all smart meter systems and products. When developing standards, financial hurdles should be kept in mind. For example, manufacturers and vendors cannot afford to make upgrades in order to comply with compatibility standards on short-time scales, especially with revenue-sensitive equipment such as meters. Additionally smart meter technology is developing rapidly and costs can be expected to decrease and functionality and security can be expected to improve. Timing for installation of smart meters should take costs and their life expectancy into consideration.
- Design the infrastructure to accommodate the potential need for large-scale charging of PHEVs and to identify vehicles for billing purposes.
- Require manufacturers and vendors of smart grid components to use open standards, like IP-based open standards, which avoid the need for full-scale replacements and technology obsolescence.

Chapter 3. CONSUMER PRIVACY

Consumer privacy is a critical issue in the context of smart grid. The potential for data mining and acquiring intimate details about consumer behavior and lifestyle is a reality. These risks may lead to major privacy issues unless a deliberate and thoughtful approach is taken to protect consumer information. The Colorado PUC should consider what level of restriction should be made for accessing this data and considering the trade-offs for commercial gain and power system reductions in energy usage. However, this should not be a categorical ex ante determination; rather, the trade-offs for improved reliability, safety, and disaster recovery should be carefully considered and weighed against individual privacy protection.

Information Ownership

- Metering and energy usage data should be considered the property of the customer, regardless of whether this data is kept by the customer, utility, or third party demand response service provider.
- Individual customer information must remain confidential.
- Individual customer information should be broadly defined as “energy or electrical usage information and billing and credit information about an individual, family, household, or residence.”
- Third party service provider (“service provider”) should be defined as “a person or corporation that is not an electrical corporation and who collects customer energy usage data and also provides equipment, software, or services that enable customers to manage or reduce their electricity usage.”

Information Disclosure

- Privacy legislation should not limit a customer’s ability to directly and voluntarily provide confidential information to a third party.
- Electrical and gas corporations, as well as demand response providers, should be prohibited from sharing a customer’s energy usage information with third parties unless the customer expressly authorizes the disclosure in writing (opt-in); additionally:
    - › Third parties should be required to acknowledge in writing that the customer information is confidential and cannot not be shared or utilized by any other person, corporation, or entity without the customer’s express written consent.

  - Should the customer authorize the utility to release confidential historical information to a third party, the customer or third party should be required to pay any reasonable administrative costs due to such release.
  - The customer's written authorization for release of confidential information should automatically expire three years from the date of authorization.

Statement of Privacy and Security Principles

- Third party service providers and electrical and gas corporations that provide smart meter technology to customer residences should be required to adopt a "statement of privacy and security principles."
- A mechanism for third party service providers to file a statement of privacy within six months of commencing services to customer residences should be considered.
- For corporations, there should be a requirement that the statement be filed with and approved by the appropriate jurisdictional authority within the utility service territory.
- As a recommendation, the privacy statement may contain some or all of the following stipulations:
  - The customer has the right to transparency in information gathering and use; that is, the utility must provide customers with meaningful, conspicuous, and comprehensive notice pertaining to collection, use, dissemination, and maintenance of individual customer information.
  - The customer has the right to participate in the process by which information about the customer is collected and used; the utility must establish a process that seeks a customer's consent for collection, use, dissemination, and maintenance of the information; the utility must provide a mechanism for customers to access and correct their information.
  - The customer has the right to know why their information is being gathered, and the utility must tell the customer the purpose for which their information is being gathered.
  - Individual information must only be used for the purposes for which it was collected and may be shared only for purposes that are consistent with the contractual or commercial purposes for which it was collected.
  - The utility must maintain the value and integrity of individual information and ensure that the information is accurate, relevant, timely, and comprehensive; the utility must provide a mechanism by which the customer can easily and confidentially access and view their information and report any errors; the utility must rectify incorrect information that is challenged by the customer.
  - The utility must maintain a secure information gathering system and must protect all information through proper security safeguards against risks of loss, unauthorized access or use, destruction, modification, or unintended or inappropriate disclosure.
  - The utility must subject itself to auditing to verify and ensure compliance with its statement of principles.
  - The utility must adopt a work plan to properly implement its statement of privacy; the work plan must be filed with the Colorado PUC; the work plan must be approved by the Colorado PUC; once the work plan is approved, it must be made publicly available on the utility's website and must allow customers to make comments and inquiries.
  - The utility must ensure that every applicable person (i.e. contractor, equipment supplier, software supplier) is aware of and agrees to follow the statement of principles and work plan.
  - The utility must immediately notify the Colorado PUC of any violation of the work plan by any employee or any other person with access to the smart grid system.
  - Demand response providers must speedily investigate and take corrective action to prevent any violation of the work plan.

    - The Colorado PUC must ensure that every smart grid deployment plan includes testing and technology standards, and must take specified actions for service disconnections.

Legal Implications

- Consider having Public utilities develop an annual report made public and including the following information:
    - The number of federal and state warrants and the number of grand jury, civil, and administrative subpoenas received by the utility in the past year that pertain to its customers.
    - The number and types of actions taken by the utility in response to each category of information request.
    - The number of customers whose utility records were produced.
    - The type of information disclosed about the utility's customers.
    - The total amount of money received by the utility to respond to each category of information request.
- Consider a requirement that the report be annually provided to a relevant governing body, such as:
    - An Office of Information Security and Privacy Protection, similar to the one instituted in California, that would be established in order to review these reports and address any information privacy issues that may ensue; this Office should be established as either a stand-alone governing body or should function as a department within the Colorado PUC.
    - The Colorado Public Utilities Commission.
    - The Rural Electric Cooperative Governing Board.
    - The City Council of the respective municipal utility.
- The holder of utility records should be required to notify the customer of the applicable order to produce the requested records, unless the court orders otherwise; if the court orders otherwise, then the order should be required to include a statement of facts as to why providing notice to the customer would impede the investigation.
    - For the purposes of privacy legislation: Personal information should be defined as "any information that identifies or describes a 'family, household, or residence.'"

Chapter 4. COST RECOVERY

The rate of recovery for investment in the smart grid system needs to be sufficient so that the desired improvements occur in a reasonable time frame from the point of view of utilities, customers, and potential investors. Failure to adequately address rate of cost recovery will lead to delays and increased costs.

- The planning and oversight stage of the cost recovery process provides valuable opportunities to address many of the issues raised elsewhere in this white paper. A failure to address those issues at the planning stage will make it very difficult for regulators to request changes from utilities later in the game.
- The cost determination stage is likely to be the most contentious, with utilities pressing for a maximum accounting of deployment costs and a conservative estimate of AMI-related cost savings. Electricity customers and their advocates will likely take the opposite position, minimizing deployment costs and estimating higher cost savings and benefits. Policy makers and regulators should strive to follow objective analysis and research regarding everything from the cost of components to the behavior of individual customers gazing at their home area network control panel while guarding against undue influence from

utilities and/or customer advocates.

- The choice of a cost recovery mechanism will likely depend on the financial needs of the state and the utility, and also on the level of support for the technology. A tracker will provide the simplest and least cumbersome regulatory process to implement, but provides very little guidance to the utility and may result in wasted investments. A surcharge may be more difficult to implement but would require utilities to plan deployment in a more rigorous manner. Inclusion of AMI in the rate base is not recommended at this time, as the process will be lengthy and expensive, and a surcharge-based cost recovery strategy may be folded into the rate base at the next regularly-scheduled rate case, after the technology has (potentially) proven its worth.

Chapter 5. COMMUNICATIONS ARCHITECTURE

- Considering the issue of "hub-and-spoke" architecture which is the primary cause of most of the issues mentioned above, a flexible communication architecture can be used to achieve a decentralized smart grid communication architecture. GridStat is one example of a communication architecture for power grids which is based on middleware framework that makes programming of power grid applications better (Washington State University, 2005). Due to its middleware characteristics which provide higher application program interface than sockets, control and monitoring applications can be implemented easily. This flexibility, quality of service, and decentralized architecture allow the communication system to provide further services to the grid (Hauser et al., 2005). It is recommended that a power grid infrastructure be deployed with GridStat.

Interoperability Issues

- These can be solved only if a set of rules and regulations are followed to achieve tight integration. Hughes (2005) and FERC (2005) have published certain rules and recommendations that should be followed to achieve interoperability.
- The boundaries of grid communication architecture should be broader than the ones present in an existing, traditional utility. The future architecture should have a scope that not only includes the revenue meters or power operations, but also spans across consumer-end equipments and substations (Hughes, 2006).
- The architecture should mainly account for only those applications that cross the traditional boundaries and have architectural significance (Hughes, 2006).
- Develop a general understanding of interoperability at several levels (GridWise™, 2005). Once all the parties have a clear understanding of the interoperability issues, which may be achieved by defining and publishing standards, only then can all the parties reach common goals (GridWise™, 2005).
- According to FERC, once the process of "path forward"—the steps to achieve interoperability—has begun, the progress of this process should be measured and recorded (2005).

Application Interoperability

- Open Connecivity protocol is tailor-made protocol for data interoperability and is therefore recommended (Kok & Kepware, 2010).
- IP is the preferred network layer protocol that should be considered for any end-to-end connectivity of smart grid devices. For those communication infrastructures that support only specific services, IP is the perfect solution as it can run over any physical layer (Lobo et al., 2008). For example, the newly developed "Open Smart Grid Communications Architecture" by Verizon Wireless and Ambient Corporation uses private IP clouds for connectivity (2010). It is recommended that the IP network utilize IPv6 addresses and should span

across the whole spectrum of smart grid infrastructure. This will allow any infrastructure to support new services. IPv6 addressing is preferred for the reason being that it can support many more devices than IPv4 without losing any network transparency.

- Furthermore, new or unsupported services can achieve end-to-end connectivity with the help of SIP (Session Initiation Protocol), an application layer protocol. It is highly recommended that SIP be used for smart grid end devices connectivity because of the following reasons:
  - SIP supports all the kinds of communications needed by smart grid devices (DiAdamo, 2009).
  - SIP runs over the IP network layer. This makes SIP independent of any underneath physical network (DiAdamo, 2009).
  - SIP is secure, scalable, reliable, and mobile (DiAdamo, 2009). For example, SIP can be used by electric cars.

Chapter 6. ELECTRIC TRANSPORTATION

Overall, the automotive market is ripe for large-scale deployment of PHEVs and EVs but certain barriers must be overcome. The following recommendations include suggestions to overcome these barriers:

- Legislating increasingly stringent CAFE standards to raise vehicle mileage standards to 45 mpg or higher, which could be accomplished by hybridizing all vehicles.
- Offset the PHEV and EV cost premium to the consumer to encourage increased purchases and put downward pressure on price through volumetric sales. These offsets can be in the form of subsidies to the purchaser, possibly greater than the current federal tax credit of up to $7,500.
- Develop state incentives or subsidies to build the charging infrastructure needed for PHEVs.
- Adjusting state laws and local policies to allow PHEV access to HOV lanes or preferred parking spaces.
- State and local governments, as well as the utilities, could help the PHEV and EV market by including PHEVs and EVs in their fleets. Specifically, this would increase the volume of early sales, offer market certainty to manufacturers and promote technology demonstrations. Even more importantly, this could facilitate testing of various charging scenarios as well as charging infrastructure needs. Furthermore, this would increase public awareness of the technology and its impacts.
- Electric utilities, in collaboration with automotive manufacturers and research institutions, should explore effectiveness and public acceptance of various PHEV managed charging scenarios.
- Utilize smart grid technologies, as well as the existing internet and mobile device resources, to enable users greater, not less, control of the charging process. Empowering and rewarding the consumer is much more likely to produce mutually beneficial effects and to help accelerate adoption of PHEVs and EVs, especially in the early stages.
- Colorado, utilities, and automotive manufacturers should support public education and awareness programs related to: PHEV and EV technologies, benefits and impacts of transportation electrifications, and public acceptance of the emerging paradigm shift in the vehicles' everyday use.
- Utilities, in collaboration with automotive manufacturers and research institutions, should continue to explore technical and economic opportunities for vehicle-to-home and vehicle-to-grid technologies.
- Effective standards related to plug-in vehicle and grid integration technologies should be further established with participation by all interested parties: utilities, the automotive industry, research institutions, and governments.

- Colorado should prepare to match federal dollars for electric power R&D, including R&D related to battery technologies, charging infrastructure, and relevant smart grid technologies.
- The state of Colorado has traditionally not been a major hub for automotive-related industries or services.
- The paradigm shift to vehicle electrification opens ample opportunity for new players, including small and start-up businesses, to have a more significant presence in the new energy economy at the intersections of emerging transportation, smart grid, renewable energy, and information technologies. Colorado state policies and incentives should be aligned to support these goals.

Chapter 7. GRID AND CYBER SECURITY

This is a challenging subject area because present systems are not secure — they can be hacked into. Security problems occur at multiple levels and include physical security, communications security, and access control for the people who communicate with the system. For the sake of cautiousness, we must assume that there are malicious people who have the desire and capacity to bring down the power grid. Multiple levels of security may need to be included for every smart grid deployment plan, and security upgrades will likely be needed for current installations. The greater the potential for damage from a security break, the more important security becomes. It is recommended that the Colorado Public Utilities Commission review the security standards that are being written by NIST to ensure that Colorado smart grid systems make use of them. It is unlikely that that any of the present or proposed systems will be made completely secure, therefore it is recommended that the Commission ask for an assessment of the potential risks from hackers and other security breaches for every proposed smart grid plan.

Asset Identification

- Identify all assets.
- Responsibility for assets: a layered approach should be adopted which gives an overview of personnel responsibilities for each particular asset, and escalations or delegations (if any).
- Information and asset classification: a detailed network diagram with classification and physical and logical access controls should be defined. Systems should be hardened to extreme levels, and checks on the integrity of the systems should be continuous.
- Categorize assets with respect to risks involved.
- Follow a cycle for assets involved, and highlight issues at each level where the power grid can be compromised.

Categorize Assets—Impact on Grid

- Categorize assets with respect to risks involved.
- Structure out detailed impacts on the grid for each asset.

Risk Assessment

- Risk management should be employed using a top-down, risk-based approach.
- Third party service delivery: utilities need to have proper documentation in place that describes the services that will and will not be provided by third-party companies. Third-party companies include smart meter vendors, firmware, IT systems providers, software providers, etc.

- There should be a formal mechanism in place to monitor and review third party services.
- Managing changes to third party services: if there are any changes to the service agreement, utilities need to determine how these changes might affect the business, whether the new issues will be incorporated, and whether the utility can deal with them. If third-party vendors need remote access to upgrade or monitor their products, the utility must determine what security issues need to be addressed.
- Introduction of distributed power storage: the PUC and the Governor's Energy Office should make sure that basic services are available 24/7 in the event of an outage (i.e. police operations, local hospitals). Outages can be dealt with efficiently by using distributed storage maintained by utilities. High priority should be given to these services.

Security Investment

- The State of Colorado should consider a requirement that utilities explicitly provide security solutions to their consumers. The levels of security to protect a continuous supply of power might differ, depending on whether the customer is an individual or an industry. For example, in the event of a power outage, emergency services should be top priority. Accordingly, utilities should prioritize service reliability dependent upon customer category.

Protect and Monitor

- *Isolation of networks* and *no inter-dependency* between neighboring smart meters, or any critical infrastructure, is the first step in creating secure networks. The less the inter-dependency, the more secure the network, which will minimize cascading effects on the power grid. The ability to isolate networks in a micro-grid configuration may allow for maintaining the advantages gained from an interconnected system.
- Colorado should consider *restricting online street maps* from disclosing the information and locations of Critical Infrastructure Systems and major power plants, as these installations and systems are relatively easy targets for terrorist attacks.
- Utilities should consider *disclosing the minimum amount of information necessary* regarding their movements, security developments, and infrastructure updates on the web, because such information might attract unnecessary attention from people whose motive is to disrupt the power grid. For example, if Utility X announces partnership with Company Y for purchase of routers, switches, and firewalls, then everyone privy to that information could potentially learn the ways in which the system can be exploited (as, for example, the system components are manufactured by Company Y, and this company uses type Z proprietary software).
- Human resources security should be rigorously addressed: i.e., strict hiring procedures, roles and responsibilities, security awareness, education and training.
- There should be a formal, recurring and iterative process for reporting information on security events and weaknesses.
- There should be continuous monitoring of the activities of internal employees, as an attack is more severe from the inside.

Review and Update

- Maintenance of equipment: quarterly checks should be performed on all critical systems to maintain the power grid.
- Change of control management.

Issues Related to the Consumer

- Consumers need to be *protected from malfunctions in HANs*. These malfunctions can be caused by interference from anyone. Colorado must consider who will bear the responsibility for malfunction issues, whether it is the consumer or HAN provider, and consider the steps to determine who tried to gain unauthorized access and tamper with the HAN.
- Similarly, the issue of *unauthorized access* to web portals must also be addressed.
- Utilities should incorporate distributed energy to make sure there is an availability of power in case of outages.

Chapter 8. IMPACTS OF SMART GRID ON CO_2 EMISSIONS

- Emphasize the importance of energy efficiency as a partner to demand response and promote expansion of renewable integration.
- Deploy demand side management policies which reward both electric utilities and consumers for the performance of energy efficiency programs.
- Seek to understand and share best practices concerning factors which will promote consumer adoption of smart grid.

Chapter 9. RETAIL PRICING STRUCTURES

The smart grid retail pricing issues addressed in Chapter 7 suggest the following recommendations for the state of Colorado:

- Encourage state agencies and universities to undertake studies and experiments to better understand the consumer response to electricity pricing signals so that regulatory bodies can promote retail pricing strategies that will have the largest impact on consumers use of electricity and demand-side management.
- Remain deliberate and cautious on introducing smart grid technologies too early in the development and adoption cycle to avoid technological dead-ends and islands.
- Promote open smart grid technology standards to encourage competition, innovation, and broad participation.
- Encourage policies and strategies that promote incremental and stated penetration of smart grid technologies. Rushed investments may result in arbitrary adoption of unproven technologies further eroding consumer confidence when technologies do not work as advertised.
- Take steps to protect consumer privacy and quickly resolve who owns consumer smart grid information.

Chapter 10. WORKFORCE DEVELOPMENT

Most workforce capacity additions will be associated with the installation and maintenance of smart grid meters and sensors. However, issues with the design and operation of communication technologies that overlay the power distribution system will require engineers who know both communications and power systems. At the present time, a large number of senior engineers and managers in the utility industry are approaching retirement. Thus, there will be an opportunity for a limited number of engineers who can design communications, control, and information systems to break into the smart grid industry. These engineers will play a very important role in the success of the smart grid; the Smart Grid Task Force needs to be aware that the best of these engineers will command top dollar and there will be nation-wide, if not world-wide, competition for their services.

- Encourage universities, colleges, and industry groups in Colorado to provide introductory smart grid workshops, courses, and boot camps to bring experienced business professionals up to speed with the utility industry and the role of smart grid within it.
- Encourage engineering schools in Colorado to develop and deliver curricula in power engineering with courses in smart grid technologies to train engineers and applied scientists to develop and design the smart grid/utility infrastructure of tomorrow.
- Encourage community colleges and technical schools in Colorado to develop programs to train technicians in those skills needed by utilities and other businesses to install and maintain the smart grid/utility infrastructure of tomorrow.
- Promote the entrepreneurial creation of new smart grid businesses and business units with proof-of-concept seed grants, technology transfer programs, and other entrepreneurial initiatives.

Chapter 11. CONSUMER BEHAVIOR

The current state of knowledge of consumer behavior and security perceptions is limited. The examples cited in this chapter only approximate the type of expected reactions and issues that may occur. Unanticipated consequences of large-scale smart grid implementation will certainly occur, although the more effort to identify potential harms, the better these can be mitigated. Based on this brief review, we can make a number of recommendations, four of which are key, for future action based on the current evidence.

Key Recommendations

- Safeguard consumers' utility data and information. Sufficient research and understanding of the long-term impacts of releasing identified energy data does not exist. As such, the Colorado PUC should proceed conservatively when evaluating how to release de-identified data, and only provide data in ways that do not result in the identification of customers. The Colorado PUC should not release identified data to cities and counties or other third parties as they will likely not understand the serious privacy and other ramifications associated with the usage and possession of such information.
- The PUC should develop a legal recourse for those wishing for greater privacy and a system to handle short-term damages for those harmed by privacy invasions.
- Conduct research on consumer responses to different types of feedback and on consumer perceptions of security and safety concerning the smart grid to provide adequate background for decision-making.
- Conduct research across a diverse array of groups to ensure proper understanding of population-wide reactions.

Additional Recommendations

- To alleviate some of this caution, more research needs to be done, particularly with highly diverse groups of people to get a sense of the population-wide reaction to smart grid devices. This not only includes basic sociodemographic differences linked with the technical data, but also attempts to understand the relationship to smart grid devices and security concerns.
- Consumers should be allowed a period of time to understand their household's feedback from the smart grid

before any evaluation of public utility bill release ("naming and shaming") is considered.

- In light of the lack of evidence concerning, for example, protection of vulnerable populations such as the disabled, the elderly, and low-income households in a smart grid context, the PUC should proceed cautiously with release of personal identifiable information generate by deployment of smart meters and technologies in the household.
- Given that smart grid privacy standards are just now being developed on the international level, the PUC should familiarize itself with privacy standards definitions before committing Colorado a comprehensive data privacy policy for the regulated utilities.

Chapter 12. SAFETY ISSUES IN DISTRIBUTED AND RENEWABLE ENERGY INSTALLATIONS

In order to reduce the risk of electrical hazards and accidents due to the issues mentioned above, we recommend the following measures:

- *Installation by trained professionals:* as in the case of roofing repairs, installation of rooftop renewable energy equipment by trained professionals would minimize the risk of injury to the end-user. There is a need for standardization of installation procedures and additional safety measures such as stairs with hand-rails instead of metal stepladders, and insulated platforms for repair and maintenance.
- *Training and education on safety procedures for end users:* after installation, the end-user should be thoroughly trained in the identification of various components in the system, distinguishing the exposed live parts of the system from the other parts of the system, and use of protective footwear and grounding equipment while repairing electrical equipment.
- *Protective fire retardant enclosures* should be used to minimize damage due to electrical fires or leakage of chemicals from batteries. Adequate clearances should be provided for maintenance of these equipments. Sealed, leak-proof batteries should be considered to prevent injuries from chemical leaks.

Chapter 13. COLORADO EMERGENCY SERVICES AND ENERGY ASSURANCE PLANNING

Suggested Steps to Develop an Energy Assurance Emergency Plan

Step 1 – Establish Guiding Principles

- The first meeting will be used to define the guiding principles in developing the Energy Assurance Emergency Plan. By involving energy emergency experts in the stakeholder workshop, the intent will be to resolve issues and accurately answer any questions about current capabilities, policies, or procedures during the workshop. While a meeting/workshop format is proposed, the managers should employ webinar presentations, surveys, phone interviews, conference calls and other means that will encourage involvement from a wider range of stakeholders.
- Buy-in and participation by stakeholders is essential in developing the plan.
- Information and capabilities shared in workshops, meetings, and other communications shall be considered confidential and proprietary and restricted to those in the plan development process.

- The basis is that the current level of assurance will be improved through cooperation, information sharing, and critical thinking.
- That policies and procedures in both the public and private sector impact the full realization of a comprehensive and effective energy assurance emergency plan.

Step 2 – Determine Public and Private Sector Responders

- It is important to identify the responders in both the public and private sectors to ensure they are included as stakeholders and to gauge their level of knowledge skills and abilities in the area of energy emergency response.

Step 3 – Present Realistic Scenarios That Will Test the Response of the Public and Private Sector

- Scenarios are a proven method for testing and exercising capabilities of response entities. The initial scenarios are used to extract weaknesses and gaps in stakeholder plans and capabilities. These will be collected in a constructive manner without criticism or highlighting of stakeholders deficiencies. The primary scenario concerns of key stakeholders will figure prominently in the early stages of this project as well as the design of further training/exercises events.
- During the early stages, scenario based discussions help clarify concerns, expected cascades and relationships, primary and secondary roles and responsibilities (which may vary based on the scenarios), procedures, possible strategies, and policy options for response and recovery.
- Based on these discussions, the managers will work with the state, county, and local planning agencies, the GEO, PUC, Colorado Department of Emergency Management, and industry stakeholders to identify the highest priority scenarios to support the intra- and inter-state training/exercise events.
- Concurrent exercise development and long-term scheduling encourage broad stakeholder exercise participation.

State Recommendations

- Partner with Colorado counties and municipalities in utilizing distributed generation technology including backup communication, in case there is a power outage.
- All emergency communication centers in Colorado should have backup plans for power to run their services. In case there is a power outage, communications should not be effected. At least 2-3 weeks of power should be stored in backup systems.
- Communication backup plans should be defined, in order to prepare and respond to man-made emergencies, terrorist attacks, or natural disasters.
- Priority for back-up-power supplies should be given to 911 services, hospitals, fire and police stations. As such, it is best to isolate these services from the main power grid and to provide them with their own separate communications channel and power distribution methods. These channels should be planned with security in mind and the probability of failure should be estimated.
- Enable power to be routed from other regions in the WECC, if possible to do so.

County and Municipal Government Recommendations

- Review the capabilities of distributed generation and how it supports emergency services for their jurisdiction.
- Validate energy supply priorities with utilities, fuel supply, and consumer distribution to ensure that essential services including hospitals, aged care, communications, and emergency operations centers are available.
- Engage in an effort to perform energy assurance planning in cooperation with surrounding jurisdictions, utilities, and the state of Colorado.
- Explore techniques for emergency services vehicles to be powered from Distributed Generation sources.
- Ensure that emergency services communications, emergency operations centers, and other critical emergency service facilities develop distributed generation plans that support a long term outage of commercial power.

Utility Recommendations

- Develop emergency backup plans.
- Specify to public the expected downtime for any power outage and how much time might be needed to repair facilities in the event of a particular emergency situation.
- Establish incident response plans for particular threats and the systems that would be compromised.
- Support efforts in the public sector to develop energy assurance plans through such efforts as building in-house expertise, working with experts, information sharing, and exercise participation.
- Identify critical assets which can be compromised via communications channel or the internet and how to protect or back up those systems.
- Logical security and physical security should be in place before implementation of the smart grid, or integration with other technologies for critical facilities.
- Utilities should isolate power distribution for emergency services from the public network because isolation is the key to protecting the smart grid.

OVERVIEW OF STATE & SELECT INTERNATIONAL SMART GRID ACTIVITIES

Angela Cifor, Sophia Lenz

ABSTRACT: *This chapter provides an overview of state and select international smart grid activities. It has four parts: (1) State Policy Actions, (2) Utility Projects, (3) Miscellaneous Smart Grid Activities, and (4) Select International Activities. A brief textual summary of each part is provided, followed by corresponding charts and graphs which provide the names and details of relevant smart grid projects and activities.*

SMART GRID STATE POLICY ACTIONS

State-level smart grid policies and activities fall into four broad categories:[1]

1) Energy programs/initiatives;
2) Energy efficiency reports/recommendations;
3) State energy or smart grid task forces/committees; and
4) Relevant smart grid legislation

However, actions vary widely from state to state. While some states have no established energy efficiency or smart grid goals, others have specific smart grid policy initiatives and legislation. California leads the nation in implementing smart grid policies and legislation, and is one of the only states that has established a statewide smart grid policy. It is also the only state to pass smart grid customer privacy protection legislation.[2] Colorado has passed some smart grid legislation and policy, placing it in the middle of the pack with regards to smart grid policy actions across all 50 states. States like Washington and California provide Colorado with examples of important policy actions to consider if Colorado intends to advance and facilitate smart grid infrastructure and technologies.

SMART GRID UTILITY PROJECTS

In general, many utilities appear to be engaging in significant smart grid deployment and testing operations. An evident trend is the use of demonstration projects to test the efficacy and feasibility of putting smart grid technologies into operation on a much larger scale. In this regard, the state of California is again the forerunner, where 13 utilities are deploying or have already deployed smart grid technologies to some extent.

Colorado has five utilities installing smart meters, and Xcel Energy's Smart Grid City initiative is taking place in Boulder. However, Colorado utility projects are currently relatively limited in their application of advanced smart grid technologies. While many utilities—including IOUs, cooperatives, and municipalities—are deploying fully-functioning smart grid networks, Colorado utilities (with a few exceptions) are primarily focused on smart meter replacements.

The most advanced projects in terms of a comprehensive end-to-end approach are Xcel's Smart Grid City project in Boulder and the City of Fort Collins Renewable Distributed System Initiative.

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[1] While the survey of state policy actions provided in the report is comprehensive, more research must be done to confirm that all state policy actions have been found and recorded.

[2] See California Public Utilities Commission, Proposed Decision of Commissioner Ryan, Agenda ID #9498 (May 21, 2010), available at http://docs.cpuc.ca.gov/efile/PD/118336.pdf.

MISCELLANEOUS SMART GRID ACTIVITIES

While electric power utilities are conducting the majority of smart grid projects and building smart grid-enabling infrastructure, private R&D companies and university research centers are also contributing to important smart grid technology developments and commercialization efforts. On the whole, non-utility projects focus on researching sophisticated smart grid-enabling technologies—such as prototype battery systems and other advanced energy storage systems. Non-utility projects and research efforts will likely continue to play an important role in the deployment, promotion, and improvement of smart grid technology across the nation.

INTERNATIONAL ACTIVITIES

While many countries are currently experimenting with smart grid technologies, four countries appear to be leading the international movement for grid modernization—i.e., Denmark, Germany, Spain, and China.

Denmark currently derives 40% of the country's electricity from wind turbines and has implemented policies to increase this figure in the near future through the use of innovative smart grid technologies. The EDISON Project is testing the feasibility of storing excess wind energy in plug-in hybrid electric vehicles (PHEVs) that can later be fed back into the grid.

Germany's MEREGIO project is striving to significantly reduce emissions in Stuttgart using smart grid technology with the hope of expanding the project to other regions across the entire country. Like the EDISON Project in Denmark, Germany's ABB Smart Grid Project is also endeavoring to develop solutions to store excess energy from the grid.

Spain's SmartCity project is attempting to cut energy usage by 20% and reduce greenhouse gas emissions considerably. Moreover, the Endesa Smart Meter program is deploying two million smart meters per year to Spain's residents.

China's Five Year Plan for the energy industry includes building large-scale smart grid projects to encompass all aspects of the power industry. Further, the City of Yangzhou has partnered with General Electric to develop a Smart Grid Demonstration Center in order to introduce GE's innovative smart grid products to the Chinese energy market.

Table 1. SMART GRID STATE POLICIES

STATE	POLICY	POLICY DESCRIPTION
Alabama		
Alaska	Alaska Energy Authority Energy Efficiency Report	Roadmap for developing energy efficiency and conservation programs and policies
Arizona	State Energy Program	Focus on energy efficiency, program expansion due to ARRA funding
Arkansas	2001 House Bill 2325	Establishment of net metering rules for certain renewable energy systems by Public Service Commission
	2007 House Bill 2334	Support HB 2325 by increasing availability of net metering, clarification of ownership of renewable-energy credits (RECs)
	2007 Act 696/House Bill 2460	Establishment of Governor's Commission on Global Warming, which recommends SG development, research, and regulation

Table 1. SMART GRID STATE POLICIES (cont'd)

STATE	POLICY	POLICY DESCRIPTION
	State Electricity Regulator's Assistance*	Increase Public Service Commission's capacity to manage imminent regulatory activity due to ARRA funding
	Energy Assurance Plan Review*	Program focused on development of new energy portfolio applications, including SG technologies, to integrate into energy assurance and emergency preparedness plans
California	2008 Senate Bill 1389	Requirement that California Energy Commission prepare biennial energy policy report discussing major energy trends and issues
	2009 Senate Bill 17	Establishment of SG state policy and requirement that Public Utilities Commission outline SG deployment plan by July 2010
	2009 Assembly Bill 64	Elevation of Renewables Portfolio Standard goal to 33% by 2020
	2010 Senate Bill 837: SG and Privacy	Established that ownership rights to energy usage/meter data belong to customers and remain confidential
	Ann.Cal.Pub.Util.Code § 8360	Establishment of state policy to modernize state's electrical system through SG technologies
	Ann.Cal.Pub.Util.Code § 8369	Regulation of SG systems
	Ann.Cal.Pub.Util.Code § 8362	Deployment plan, requirements, and rule-making for SG
	2009 Integrated Energy Policy Report	Established to satisfy requirements of SB 1389, provides recommendations for energy actions
	Senate Select Committee on SG	Created to provide legislative oversight of SG technology implementation
Colorado	2010 Senate Bill 180	Creation of SG Task Force
	C.R.S.A. § 40-2-123	Discussion of new energy technologies, considerations, definitions, and demonstration projects
Connecticut	Public Act 07-242, § 98	Requirement that utilities submit plan to deploy advanced metering systems capable of tracking hourly consumption electricity rates
Delaware		
Florida	2006 Senate Bill 888	Creation of Florida Energy Commission to make recommendations on renewable energy sources
Georgia		
Hawaii	Hawaii Rev. Stat. Chap. 226-18(c)(6)	Promotion of research, development, demonstration, and use of energy efficiency programs and technologies
	Hawai'i Clean Energy Initiative	Goal of meeting 70% of Hawaii's energy needs with clean energy by 2030
Idaho	Idaho Strategic Energy Alliance	Established to provide credible analyses and information on energy issues for stakeholders, decision-makers, and the public
Illinois	2010 House Bill 6154	Amendment to Public Utilities Act, requirement that Illinois Commerce Commission adopt minimum standards for SG technology
	2010 House Bill 6202	Creation of Net Metering Task Force
Indiana	IC 5-28-34-2	Adjustment of definition of "green industry" to include SG

Table 1. SMART GRID STATE POLICIES (cont'd)

STATE	POLICY	POLICY DESCRIPTION
Iowa	House File 918	Establishment of Office of Energy Independence to provide recommendations for energy independence, including SG development and deployment
Kansas	Executive Order 08-13 (DISSOLUTION)	Dissolution of Kansas Energy Council
	Executive Order 08-03	Establishment of Kansas Energy and Environmental Planning Advisory Group (KEEP) to identify opportunities for Kansas to become more energy efficient
	2009 House Bill 2038	Provides full cost-recovery and return on investment for utilities that adopt energy efficient technologies, as permitted by state corporation commission
	2009 House Resolution 6005-0	Establishment of goal of making 25% of electric meters SG compliant
Kentucky	Energy Plan Report	Provision of energy efficiency recommendations, establishment of mid-term and long-term actions for SG development
Louisiana		
Maine	2009 Senate Paper 676	Partnership between Efficiency Maine Trust and Public Utilities Commission to consider utility incentives, regulations, and technologies pertaining to SG
	2009 House Paper 1108	Assurance that state's Energy Corridor Policy does not impact state's Renewable Power Development when considering SG technologies
	2010 House Bill 1535	Creation of SG State Policy
	State of Maine Comprehensive Energy Plan	Recommendations for development of SG policies
Maryland	House Bill 1072 (FAILED)	Provision of SG Initiative
	EMPower Maryland legislation	Establishment of goal to reduce energy consumption by 15% by 2015
Massachusetts	Green Communities Act	Establishment of comprehensive bill to encourage various facets of energy reform
Michigan		
Minnesota	2009 S.F. 1537	Establishment of regulations for energy technology development, requirement of neighborhood energy reduction report
	2010 S.F. 2971	Establishment of SG development and implementation plans
	2010 S.F. 3219	Requirement that utilities submit SG development and implementation plans
Mississippi	2010 House Bill 1356 (FAILED)	Encouragement for utilization of SG systems by utilities, regulated by Public Service Commission
Missouri		
Montana	2009 Drafts 51	Creation of SG task force to consider and develop SG deployment plan
Nebraska	2009 Legislative Bill 436	Implementation of smart metering systems in residential homes, costs to be incurred by utilities

Table 1. SMART GRID STATE POLICIES (cont'd)

STATE	POLICY	POLICY DESCRIPTION
Nevada	2009 Senate Concurrent Resolution 19	Appointment of committee to conduct a study reviewing SG technologies and their suitability in Nevada
New Hampshire		
New Jersey	2008 Assembly Joint Resolution 121	Encouragement of Congress to enact the American Clean Energy and Security Act of 2009
	2008 Senate Bill 2428	Authorization of public utilities to implement formula-based rates
	2010 Assembly Bill 912	Establishment of cost-recovery mechanism for equipment compatible with SG
	2010 Assembly Bill 913	Establishment of SG Pilot Program and SG Technology Research Center at Rutgers University
	2010 Assembly Bill 915	Establishment of AMI standards and regulations
New Mexico	2009 Senate Bill 477	Consideration of future test periods in determining rates
New York	2009 Assembly Bill 6954	Acknowledgment and establishment of SG system
	NY State SG Consortium	Utilization of public-private partnerships to evaluate, develop, and implement SG projects
North Carolina	2009 Senate Bill 1440	Creation of joint broadband/SG task force to develop comprehensive overview of SG technologies, implementation, and efficacy
	North Carolina's Energy Future Report	Key recommendations for implementation of SG policies and technologies in the state
North Dakota		
Ohio	2008 Senate Bill 221	State policy established to encourage AMI implementation
Oklahoma	Oklahoma Energy Security Act	Development of renewable energy standards, including promotion of demand side management
Oregon	2009 Senate Bill 80	Establishment of Climate Policy Advisory Council to coordinate state agency actions, including SG measures, to reduce GHG emissions
	Oregon Smart Grid Resiliency Initiative	Preparation of Workforce Development Plan to investigate aspects of SG applications, strengths, and weaknesses
Pennsylvania	2008 Act 129	Requirement that utilities with 100,000+ customers establish smart meter installation plans
Rhode Island	2009 Senate Bill 485	Development of renewable energy generation by promoting SG demonstration projects, including implementation of smart meters
	Senate Bill 2851	Amendment to implement smart meters and SG demonstrations
South Carolina		
South Dakota	2009 Senate Bill 60	Authorization of public utilities commission to implement SG policies pursuant to 2007 EISA

Table 1. SMART GRID STATE POLICIES (cont'd)

STATE	POLICY	POLICY DESCRIPTION
Tennessee	Tennessee Valley Authority	Consideration and distribution of appropriate SG information and pricing to utilities pursuant to 1978 Public Utility Regulatory Policies Act and 2007 EISA
	Tennessee Regulatory Authority	Host of SG Technology Summit to discuss present and future utilization of SG technologies in the state
Texas	2005 House Bill 2129	Encouragement that SG networks be deployed as quickly as possible
	2007 House Bill 3693	Requirement that commission establish cost recovery mechanism for utilities that deploy AMI technology
	2009 House Bill 4098	Allowance for surpluses in solar generation to be re-distributed for a price determined by the presence of advanced metering systems
	2009 House Bill 4458	Development of program by state energy conservation office to use available funds to support SG demonstration projects
Utah	SG Work Force Training Programs*	Development of program to train over 30,000 workers to modernize SG and implement new technologies
Vermont	2009 Senate Bill 137	Acknowledgment that economic growth might benefit from implementation of SG technologies and creation of Green Growth Zones
	2009 Senate Bill 288	Applicant may propose and board may approve or require applicant to adopt a rate design that includes dynamic pricing
	2009 House Bill 313	Pursuit of ARRA funding opportunities by the department of public service to implement SG technologies, projects, and workforce training
Virginia	2009 House Joint Resolution 704	Requirement that state corporation commission review and evaluate an increase in implementation of SG technologies, specifically smart meters, in the state
	2009 Senate Bill 1348	Requirement that state corporation commission develop a study that considers other states' SG deployment measures and evaluates SG technologies
Washington	2007 House Bill Amendment to Senate Bill 6001	Development of policies by utilities and transportation commission to encourage meeting energy requirement through the use of many projects, including implementation of SG technologies
	2009 Senate Bill 5625	Creation of state college with focus on clean energy and SG technologies
	2009 Senate Bill 5921	Creation of clean energy collaborative among universities, businesses, and laboratories and creation of a clean energy strategy
	2009 House Bill 2289	Modification of energy freedom program to receive federal funding to implement SG technologies
	2009 House Bill Amendment to Senate Bill 5735	Allowance for qualifying utilities to count investments in SG technologies at three times base value

Table 1. SMART GRID STATE POLICIES (cont'd)

STATE	POLICY	POLICY DESCRIPTION
	Washington Clean Energy Leadership Council: Interim Report	Recognition of SG technologies as an area of opportunity for clean energy
	Washington Energy Policy Division: Report in Response to 2007 Legislature	Consideration of national best practices for SG technologies and their potential for implementation in the state
West Virginia	2010 House Bill 4012	Provision that commission evaluate cost-effectiveness of SG technologies in reducing consumption and peak demand of electricity
	West Virginia SG Implementation Plan (WV SGIP)	Assessment of current electric grid technologies to evaluate potential of implementing SG technologies within the state
Wisconsin	Wisconsin Energy Assurance and SG Resiliency Plan	Plan to acquire federal funding to better coordinate and communicate SG reliability and security
Wyoming		
District of Columbia	2009 Legislative Resolution 311	AMI Implementation and Cost Recovery Authorization Emergency Declaration Resolution
	2009 Legislative Resolution 476	Creation of a PEPCO D.C. jobs program by way of AMI deployment
Legend	* = funded by ARRA	SG = smart grid

Chart 1. NUMBER OF RELEVANT STATE SMART GRID POLICIES

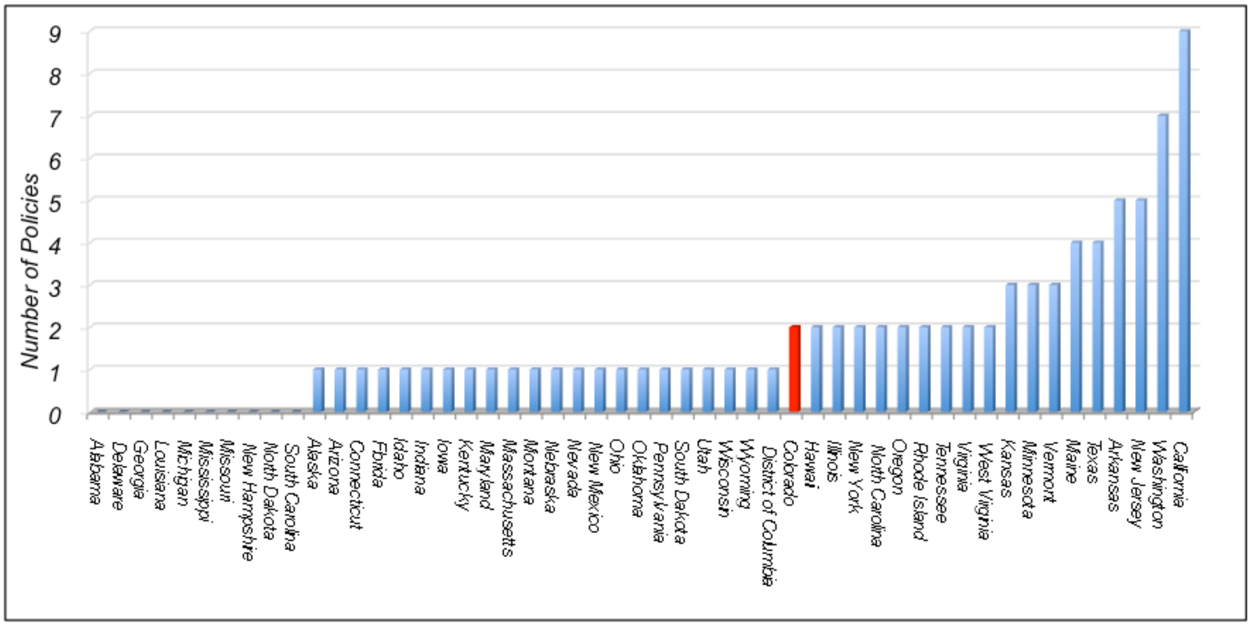


Chart 2. CATEGORIZATION OF RELEVANT STATE SMART GRID POLICIES

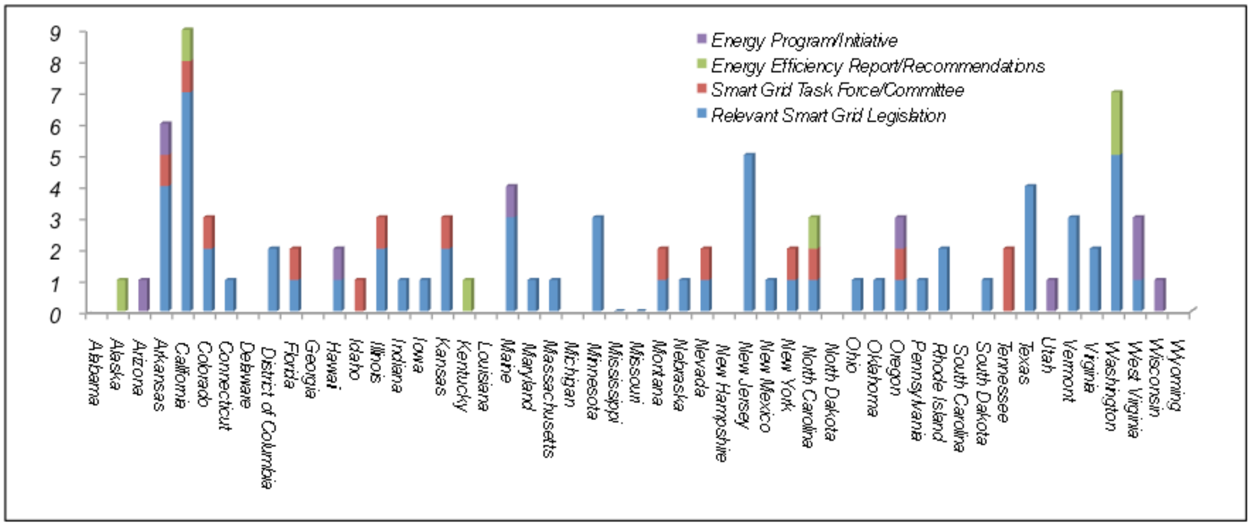


Table 2. SMART GRID UTILITY PROJECTS

STATE	UTILITY	IOU	NON-IOU	ARRA	PROJECT DESCRIPTION
Alabama	Alabama Power (Southern Company Subsidiary)	X		X	Provide all customers with smart meters by 2011, installation started in 2008
Alaska	Chugach Electric Association		X		WattBuster Research Project: evaluating effectiveness of building performance monitoring as incentive to implement energy efficiency and conservation measures
Arizona	APS (AZ Power Service)	X			Pilot project in Flagstaff, install 30,000+ meters in homes and businesses
	Southwest Transmission Cooperative		X	X	Install smart meters for 44,150+ customers
	Navajo Tribal Utility Authority		X	X	SG Work Force training
Arkansas	Woodruff Electric		X	X	Install AMI to provide time-of-use data, help monitor demand, and reduce outages
California	Silicon Valley Power		X		AMI installation for residential & commercial electric customers, integrate all water meters into system
	San Francisco Public Utilities Commission		X		Water utility: install AMI meters to track water consumption
	Southern California Gas Company	X			Upgrade all gas meters with advanced meters
	Burbank Water and Power		X	X	AMI system for Energy Demand Management programs and enhanced grid security systems
	Modesto Irrigation District		X	X	Install 4,000 smart meters, enhance electricity distribution system to help reduce peak demand and overall system losses
	Sacramento Municipal Utility District		X	X	Install a comprehensive regional SG system from transmission to customer

Table 2. UTILITY SMART GRID PROJECTS (cont'd)

STATE	UTILITY	IOU	NON-IOU	ARRA	PROJECT DESCRIPTION
	City of Glendale Water & Power Utility		X	X	Will install 84,000 smart meters and meter control system
	San Diego Gas and Electric Company	X		X	Implement advanced wireless communications system to provide connection smart meters, all customers scheduled to have smart meters by end of 2011
	City of Anaheim Utility		X	X	Installing 35,000 residential meters, as well as security and data systems
	Los Angeles Department of Water and Power		X	X	SG Demonstration Project: SG cybersecruity testing and PHEV grid testing
	Southern California Edison Company	X		X	SG Demonstration Project: demonstrate an integrated, scalable SG system
	Southern California Edison Company	X		X	SG Demonstration Project II: evaluate a wider range of applications for lithium-ion batteries that will spur broader demand for lithium-ion batteries
	Pacific Gas & Electric Company	X		X	SG Demonstration Project: build and validate design, performance, and reliability of an underground Compressed Air Energy Storage plant
Colorado	Xcel Energy	X			Deploy SG system in Boulder
	Black Hills/CO Electric Utility Co			X	Install 42,000 smart meters and communications infrastructure to facilitate meter reading, provide a pilot for a dynamic pricing program
	City of Fort Collins Utility		X	X	Installing 79,000 smart meters and in-home demand response systems.
	Colorado Springs Utilities		X		Installing AMI system
	City of Fountain Utility		X	X	Install 14,600 smart meters, extend fiber optic network, deploy outage management system (partnership with Loveland, Longmont and Ft. Collins)
	Delta Montrose REA		X		Installed 31,000 smart meters
Connecticut	Connecticut Light and Power	X			Installed 4000 smart meters, undertook trials to evaluate SG opportunities
	Metropolitan District		X		Deploying AMR system
	Connecticut Municipal Electric Energy Cooperative		X	X	Building regional smart meter network infrastructure, including 5 municipal utilities and at least 13,000 meters
Delaware	Delmarva Power	X			Replacing all meters with AMI
Florida	Tampa Electric Co	X			Successfully tested AMI for multi-occupant buildings
	Gulf Power(Southern Company Subsidiary)	X		X	Replacing all meters with smart meters
	Florida Power & Light Company	X		X	Installing over 2.6 million smart meters, 9,000 intelligent distribution devices, 45 phasors, and advanced monitoring equipment in over 270 substations

Table 2. UTILITY SMART GRID PROJECTS (cont'd)

STATE	UTILITY	IOU	NON-IOU	ARRA	PROJECT DESCRIPTION
	Lakeland Electric	X		X	Installing 125,000+ smart meter network for residential, commercial and industrial electric customers across utility's service area
	City of Leesburg		X	X	Deploying smart meter network, energy management for municipal buildings, integrated distributed generation, and new substation
	JEA	X		X	Installing 3,000 smart meters with two-way communications, introducing dynamic pricing pilot, enhancing IT system, and implementing consumer engagement software
	City of Tallahassee		X	X	Implementing demand response program, including smart thermostats and advanced load control systems for residential and commercial customers
	Talquin Electric Cooperative		X	X	Installing smart meter network for 56,000 residential and commercial customers
	City of Quincy		X	X	Deploying SG network across entire customer base, including two-way communication and dynamic pricing
	Progress Energy	X		X	Deploying additional AMI and demand response infrastructure
Georgia	Georgia Power (Southern Company subsidiary)	X		X	Replacing all meters with smart meters
	Suwannee EMC		X		Implementation of 150,000 Sensus Flexnet meters between 2009 and 2012
	Jackson EMC		X		Implementation of 220,000 Sensus FlexNet meters, staring in 2009 and finishing in 2012
	Municipal Electric Authority of Georgia		X	X	Installing IT and SG upgrades throughout the system
	Cobb Electric Membership Corporation		X	X	Deploying 190,000 smart meters, covering 100% of customer base
	TriState Electric Membership Cooperation		X	X	Installing 15,000+ smart meters to enable dynamic pricing options and expanding line monitoring for improved outage detection
Hawaii	Kauai Department of Water		X	X	Replacing all 20,000 existing water meters with AMR transmitters and GPS chips
	Hawaii Electric Co. Inc.		X	X	Deploying electric distribution system to reduce outage duration and to automate high load distribution circuits feeding eastern Oahu
Idaho	Idaho Power	X		X	Deploying a smart meter network for all 475,000 customers and implementing an outage management system and irrigation load control program
Illinois	ComEd Trial (Exelon Company)	X			Deploying 141,000 smart meters in 11 suburban communities and in Chicago

Table 2. UTILITY SMART GRID PROJECTS (cont'd)

STATE	UTILITY	IOU	NON-IOU	ARRA	PROJECT DESCRIPTION
	Ameren Illinois Utilities	X			More than half of 1.2 million customers have automated meters that were installed over the last four years
	City of Naperville		X	X	Deploying 57,000+ smart meters and installing infrastructure and software to support and integrate smart grid functions and info flow between utility and customers
Indiana	Duke Energy Indiana	X			Proposing SG implementation plan with 2-way communications for meters, web portals for customers, remote load switching
	NIPSCO	X			Conducting formal studies to determine feasibility of implementing SG technology
	Whitewater Valley		X		Selected Tantalus to deploy SG system
	Indianapolis Power and Light Company	X		X	Installing 28,000+ meters, for commercial and residential customers, providing energy use information to customers and enabling 2-way control capabilities
	City of Auburn		X	X	Installing a smart meter network, upgrading cyber security technologies, expanding grid monitoring, and improving responses to power outages
Iowa	Des Moines Water Works		X		Installed smart meters for 50% of customers to provide daily readings
	Alliant Energy	X			Installing 1M electric and 450,000 gas meters
Kansas	Midwest Energy Inc	X		X	Upgrading electric transmission systems to increase reliability and facilitate integration of renewable energy
	Westar Energy, Inc	X		X	Deploying SG technology to build a SG city
Kentucky	Kentucky Power	X			In 2006, installed 186,00 AMI meters
	Northern Kentucky Water District		X		Engaging in 12 month exercise to retrofit radio frequency devices to existing metering
	South Kentucky Rural Electric Cooperative		X	X	Upgrading system to a smart meter network for 66,000+ families and businesses in rural KY
	Duke Energy	X		X	Comprehensive grid modernization, installing 120,000 electricity and 90,000 gas smart meters
Louisiana	Gulfport Municipality		X		Installing AMR water metering
	Entergy Services, Inc	X		X	Installing 11,000+ residential smart meters and in home display devices, coupled with dynamic pricing
	City of Ruston		X	X	Developing a fully-functioning SG: automating electricity distribution, deploying smart meter network, and data management system
	Cleco Power LLC Smart	X		X	Deploying a smart metering network, installing 275,000+ meters.

Table 2. UTILITY SMART GRID PROJECTS (cont'd)

STATE	UTILITY	IOU	NON-IOU	ARRA	PROJECT DESCRIPTION
Maine	Central Maine Power Company	X		X	Deploying a smart meter network for all residential, commercial, and industrial customers in utility's service territory, installing 650,000 meters
Maryland	Pepco	X			Installing smart meters in all Maryland customer homes
	Baltimore Gas and Electric Company	X		X	Deploying smart meter network and advanced customer control system for 1.1 million residential customers
	Potomac Electric Power Co.	X			Installing 570,000 smart meters with network interface in the Maryland service area
Massachusetts	Western Massachusetts Electric Company	X			500 meter pilot for smart meters and smart grid, as instructed by MA PUC as part of the Green Communities Act
	National Grid US	X			Two-year pilot to implement and study smart grid applications in Worcester, Mass (largest pilot in New England, involving 15,000 customers)
	Boston Water and Sewer Commission		X		Installed the SmartRead solution in 2002, using a fixed network wireless communications infrastructure
	ISO New England	X		X	Deploying AMI to provide real-time measurement of electrical quantities from across the power system
	NSTAR Electric Company	X		X	SG Demonstration Project: implement SG pilot to examine automate metering technologies
	NSTAR Electric Company	X		X	SG Demonstration Project II: demonstrate use of advanced monitoring technology to improve grid reliability and safety
	Marblehead Municipal Light Department		X	X	Install 10,000 smart meters and a pilot program to assess the effectiveness of real-time pricing and automated load management.
Michigan	Consumers Energy				Smart meter exercise: provide smart meters to 1.8M customers
	Battle Creek		X		Upgrading 14,000 previously installed smart meters
	Marshall City		X		Plans to install 5,500 electricity and 5,000 water meters
	Waterford Township Department of Public Works		X		Installing wireless fixed network for water metering; as of Oct. 2008, installed 1,000 of 28,000 meters
	Eastpointe City		X		Using read-by-radio service for water metering; meters read 2x/day
	DTE Energy	X			$300M project to install 2.7M meters for residential customers starting 2007, complete within 5 years
	The Detroit Edison Company	X		X	SG demonstration project: install 660,000 smart meters to enable dynamic pricing and grid system improvements

Table 2. UTILITY SMART GRID PROJECTS (cont'd)

STATE	UTILITY	IOU	NON-IOU	ARRA	PROJECT DESCRIPTION
Minnesota	Minnesota Power	X		X	Expanding Minnesota Power's existing smart meter network, deploying additional 8,000 meters and new measurement and automation equipment
Mississippi	Mississippi Power(Southern Company Subsidiary)	X		X	Replacing all meters with smart meters
	South Mississippi Electric Power Association		X	X	Install 240,000 smart meters and SG infrastructure across a range of SMEPA's member cooperatives
Missouri	Laclede Electric Cooperative		X		Installing a Tantalus RF based network based on Itron Centron metering
	Kansas City Power & Light Company	X		X	SG Demonstration Project: demonstrate an end-to-end SG network
	City of Fulton		X	X	Replace 5,000+ current electric meters with a smart meter network that includes a dynamic pricing program to reduce consumer energy use
Montana	Grasslands Renewable Energy, LLC	X			Wind Spirit Project: proposed system to link wind farm energy to provide constant output of clean "baseload" energy
Nebraska	Stanton County Public Power District		X	X	Installing 2,400 smart meters for AMI
	Cuming County Public Power District		X	X	Installing communications equipment and software in homes to enable SG distribution functions
Nevada	NV Energy, Inc.	X		X	Integrating SG technologies along with 1.3M smart meters
	NV Energy, Inc. & Comverge	X			Expanding existing SG program: largest demand response program in industry
New Hampshire	New Hampshire Electric Cooperative		X	X	Modernizing distribution and metering system through installation of advanced meters
New Jersey	Atlantic City Electric Corp.		X	X	Installing 25,000 direct load control devices, grid sensors, and improving communications infrastructure to optimize grid reliability and operation
	Jersey Central Power and Light	X			Testing integration of SG technologies into existing systems
	Public Service Electric and Gas	X			Developing communication infrastructure to facilitate future implementation of SG technologies
New Mexico	El Paso Electric Co.	X		X	Installing SG automation response systems to improve power restoration during outages
	Public Service Co. of New Mexico	X		X	SG Demonstration Project: demonstrate how a flow battery and control system turns a PV installation into dispatchable distributed generation resource
	Los Alamos Dept. of Public Utilities & NEDO		X		Proposed plans to set up SG demonstration projects in Los Alamos to test a residential-based SG

Table 2. UTILITY SMART GRID PROJECTS (cont'd)

STATE	UTILITY	IOU	NON-IOU	ARRA	PROJECT DESCRIPTION
New York	ConEdison of N.Y.	X		X	Deploying wide range of grid-related technologies to make grid more efficient
	ConEdison of N.Y.	X		X	SG Demonstration Project: demonstrate a scalable, cost-effective SG prototype that promotes cyber security and increases reliability and energy efficiency
	N.Y. Independent System Operator			X	Deploying range of SG technologies across NY to work in concert with existing control and monitoring systems
	Long Island Power Authority		X	X	Partnering with SUNY to develop SG corridor along Route 110
	Power Authority of the State of New York		X	X	SG Demonstration Project: demonstrate impact Dynamic Thermal Circuit Ratings technology can have on areas of N.Y. with wind generation potential
North Carolina	Duke Energy Carolinas, LLC	X		X	Install 45 phasor measurement units and upgrade communications infrastructure
	Progress Energy Service	X		X	Building a green SG virtual power plant
	Wake Electric Membership Corp.		X	X	Pilot for 100 residences to test new SG technologies
North Dakota					
Ohio	FirstEnergy Corp.	X		X	Modernize current electrical grid and reduce peak load demand using SG technologies
	Columbus Southern Power Co.	X		X	SG Demonstration Project: demonstrate secure, interoperable, and integrated SG infrastructure
Oklahoma	Oklahoma Gas and Electric, Co.	X		X	Deploy SG network that will provide 771,000 meters to 100% of customers
Oregon	Pacific Northwest Generating Cooperative		X	X	Implement SG technology to integrate 15 electric cooperatives across 4 states
	Central Lincoln People's Utility District		X	X	Provide two-way communication between utility and its consumers using SG technology
	Portland General Electric	X		X	Northwest SG Demonstration Project: develop a demonstration project in Salem to document how SG technologies can help improve electrical system's reliability
Pennsylvania	Wellsboro Electric Co.	X		X	Deploy smart meter network systems throughout the utility's service territory
	PPL Electric Utilities Corp.	X		X	Implementation of SG technologies to monitor and control grid in real-time
	PECO Energy Co	X		X	Upgrade communication infrastructure and deploy smart meters to all customers
South Dakota	Black Hills Power, Inc.	X		X	Installation of SG technologies to develop fully-operating SG system in service area
	Sioux Valley Southwestern Electric Cooperative, Inc.		X	X	Installation of smart meters for entire customer base
Tennessee	Memphis Light, Gas and Water Division	X		X	Installation of high-speed data communication and control system to serve as backbone for future SG technologies

Table 2. UTILITY SMART GRID PROJECTS (cont'd)

STATE	UTILITY	IOU	NON-IOU	ARRA	PROJECT DESCRIPTION
	Electric Power Board of Chattanooga	X		X	Deploying smart meters for entire customer base
	Knoxville Utilities Board		X	X	Deployment of smart meters and substation automation to territory surrounding University of Tennessee
Texas	CenterPoint Energy	X		X	Deployed 2.2. million smart meters; strengthening SG system to protect against natural disaster
	Reliant Energy Retail Services, LLC	X		X	Installing a suite of smart meter products, enabling customers to manage their electricity usage
	Denton County Electric Cooperative		X	X	Deployment of SG technologies for a smart meter network
	El Paso Electric	X		X	Install distribution automation to increase the monitoring and control of the distribution system during restoration
	Golden Spread Electric Cooperative, Inc.		X	X	Installation of 70,000 smart meters along with other SG technologies
	Oncor Electric Delivery Co., LLC	X		X	SG Demonstration Project: demonstrate Dynamic Line Rating (DLR) monitoring technology
	Texas-New Mexico Power	X			Deployment of smart meters using cellular network.
	Bluebonnet Electric Cooperative, Inc.		X		Deployed nation's first implemented SG system
Utah					
Vermont	Vermont Transco, LLC	X		X	Expand the deployment of Vermont smart meters from 28,000 to 300,000, and implement customer systems
	Central Vermont Public Service	X		X	Introduction and implementation of AMI technology to consumer base as part of broader SG project plans in Vermont
Virginia	Northern Virginia Electric Cooperative		X	X	Expand SG technologies to reduce peak demand
	Rappahannock Electric Cooperative		X	X	Implementation of SG technology to reduce peak demand and improve reliability
	National Rural Electric Cooperative Assn		X	X	Install enhanced demand and distribution management system
	Virginia Dominion Power	X			Installation of smart meters as part of a multi-phased evaluation of SG technologies
Washington	Avista Utilities	X		X	Implementation of SG distribution management system and communication network
	Snohomish County Public Utilities District		X	X	Installation of SG framework on utility side to allow for future deployment of SG technologies
West Virginia					
Wisconsin	Wisconsin Power and Light Co.	X		X	Implementation of power factor management system to coordinate with current smart meter network

Table 2. UTILITY SMART GRID PROJECTS (cont'd)

STATE	UTILITY	IOU	NON-IOU	ARRA	PROJECT DESCRIPTION
	American Transmission Co., LLC	X		X	Maximization of phasor measurement networks by building fiber optics communication network, installation of additional phasor measurement units
	Madison Gas and Electric Co.	X		X	Installation of smart meter network along with charging stations and management systems for HPEVs
	Waukesha Electric Systems	X		X	SG Demonstration Project: demonstrate SG compatible fault current limiting superconducting transformer for utility substation
Wyoming	Cheyenne Light, Fuel and Power Co.	X		X	Installation of smart meters and communications infrastructure
	Powder River Energy Corp.		X	X	Development of new and secure communication and data system providing additional monitoring and control of critical grid substations

Table 3. MISCELLANEOUS SMART GRID PROJECTS

STATE	ORGANIZATION	ARRA FUNDED	PROJECT DESCRIPTION
Arizona	Western Electricity Coordinating Council	X	Install transmission real-time awareness and improve integrated system awareness
Arkansas	University of AR National Center for Reliable Electric Power Transmission		Advanced research facility dedicated to creation of SG
California	Amber Kinetics, Inc.	X	SG Demonstration Project: develop and demonstrate flywheel technology for use in grid-connected, low-cost bulk energy storage applications
	Primus Power Corporation	X	SG Demonstration Project: deploy EnergyFarm to replace planned fossil fuel plant
	The Seeo, Inc	X	SG Demonstration Project: develop and deploy prototype battery system for utility scale operations
	M2M Communications	X	Installing SG-compatible irrigation load control systems in CA's central valley agricultural area to reduce peak electric demand in CA
Florida	Intellon Corporation	X	Modifying existing power line communications to enhance SG functionality
Georgia	Georgia System Operations Corporation	X	Upgrading IT systems to instantaneously communicate grid disruption information
Illinois	Beacon Power Corporation	X	Design and operate utility scale 20 MW flywheel energy storage frequency regulation plan in Chicago
Indiana	Midwest Independent Transmission System Operator	X	Will install and monitor 150 phasor measurement units in strategic locations across Midwest on independent transmissions system operators
Iowa	Iowa Association of Municipal Utilities	X	Implementing load control and dynamic pricing program using smart thermostats and web-based energy portals

Table 3. MISCELLANEOUS SMART GRID PROJECTS (cont'd)

STATE	ORGANIZATION	ARRA FUNDED	PROJECT DESCRIPTION
Maryland	Maryland Energy Administration		Create state SG analysis and determine feasibility of SG technology implementation
Massachusetts	Premium Power Corporation	X	SG Demonstration Project: demonstrate competitively-priced, multi-megawatt, long-duration advanced flow batteries for utility grid applications
	Honeywell International, Inc	X	Provide automated peak pricing response for approximately 700 commercial and industrial customers
	Whirlpool Corporation	X	Support manufacturing of smart appliances to accelerate commercialization of smart appliances capable of communicating with SG technologies
Missouri	Boeing Company	X	SG Demonstration Project: demonstration of advanced SG software technology with military-grade cyber-security
Montana	Grasslands Renewable Energy, LLC	X	Plan to develop a SG transmission system to generate wind power across Montana
New Hampshire	Southern NH University Project		Testing real-time controllers for PHEVs that respond to price signals from SG
New Mexico	Ktech Corporation	X	SG Demonstration Project: demonstrate a prototype flow battery that can be grid connected and scaled to utility power levels
North Carolina	Duke Energy Business Services, LLC	X	Developing comprehensive grid for Duke Energy's Midwest electric system, including deployment of plug-in vehicles
Ohio	City of Westerville	X	Conversion of electricity and water meters to SG network
	City of Wadsworth	X	Deployment of smart meters
Oregon	Software Association of Oregon		Entrepreneurial approach to development of SG in Oregon
Pennsylvania	PJM Interconnection, LLC	X	Deploying phasor measurement units across 10 states to measure real-time data
	East Penn Manufacturing Co.	X	SG Demonstration Project: demonstrate economic and technical viability of grid-scale, advanced energy storage system using the lead-carbon UltraBattery
Texas	Center for the Commercialization of Electric Technologies	X	SG Demonstration Project: use SG technology to manage fluctuations in wind power in the large Electric Reliability Council of Texas
	Pecan Street Project, Inc.	X	SG Demonstration Project: develop and implement Energy Internet microgrid by building on Austin Energy's existing SG programs
	Duke Energy Business Services, LLC	X	SG Demonstration Project: deploy wind energy storage demonstration project at Notrees Windpower Project in western Texas
Utah	Western Electricity Coordinating Council	X	Installation of over 250 phasor measurement units across Western Interconnection and create communication system for real-time data collection
	ATK Launch Systems	X	SG Demonstration Project: demonstrate benefits of SG technology
Vermont	UVM Clean Energy Fund Proposal: Solar Power and SG Technology for UVM		Development of SG laboratory for educational purposes and to prepare the university for forthcoming advancements in electrical technology
	Vermont Energy Investment Corporation: SG White Paper		Discusses policy and program opportunities found within SG technology implementation

Table 3. MISCELLANEOUS SMART GRID PROJECTS (cont'd)

STATE	ORGANIZATION	ARRA FUNDED	PROJECT DESCRIPTION
Washington	Battelle Memorial Institute, Pacific Northwest Division	X	SG Demonstration Project: demonstrate and validate new SG
West Virginia	Allegheny Energy and Research Ridge Test Facility		SG Demonstration Project: development of one of three Advanced Utility Infrastructure projects

Table 4. SELECTED INTERNATIONAL SMART GRID ACTIVITIES

COUNTRY	PROJECT/POLICY	DESCRIPTION
Denmark	Heavy reliance on dispersed power sources	Currently receives 40% of electricity from wind turbines
	Government policy of mandatory access to grid	Helped to spur wind power boom
	Electric Vehicles in a Distributed and Integrated Market using Sustainable Energy and Open Networks (EDISON) Project	V2G experiment that evaluates storage of excess wind energy in PHEVs to later feed energy back to grid
Germany	Minimum Emissions Region (MEREGIO)	Pilot project formed to create an optimized and sustainable power network to reduce carbon dioxide emissions
	ABB SG Project	Demonstration of implementation of SG technologies to develop solutions for storage of excess power from grid
Spain	Endesa Smart Meter Deployment	Deployment of 2 million smart meters per year and dispersal of information with hope of triggering SG legislation
	SmartCity	Project to cut energy by 20% and significantly reduce GHG emissions
China	5-Year Plan	Build Wide Area Monitoring System (WAM) and deploy PMU sensors at its largest generating facilities
	GE and City of Yangzhou Partnership: Smart Grid Demonstration Center	Showcase GE SG products to Chinese SG market
	JUCCCE China SG Cooperative	Stimulation of interest in SG technologies, planning, and implementation and identification of key Chinese leaders in the industry

SMART GRID ARCHITECTURE AND AN OVERVIEW OF ENERGY STORAGE, GRID STABILITY, AND INTEROPERABILITY

Akash Shyam Agrawal, Professor Frank Barnes, Professor Ewald Fuchs, Purva Basvraj Adke, Puneet Pasrich

ABSTRACT: *Engineering a stable, interoperable, well-planned smart grid requires considering a number of disparate factors simultaneously in the design process. This chapter begins with an overview of the smart grid architecture. Further, it explores how the smart grid can address load balancing needs, integrate renewable energy generation through energy storage, and ensure that the myriad forms of communications and control technology can interact well together across an end-to-end smart grid.*

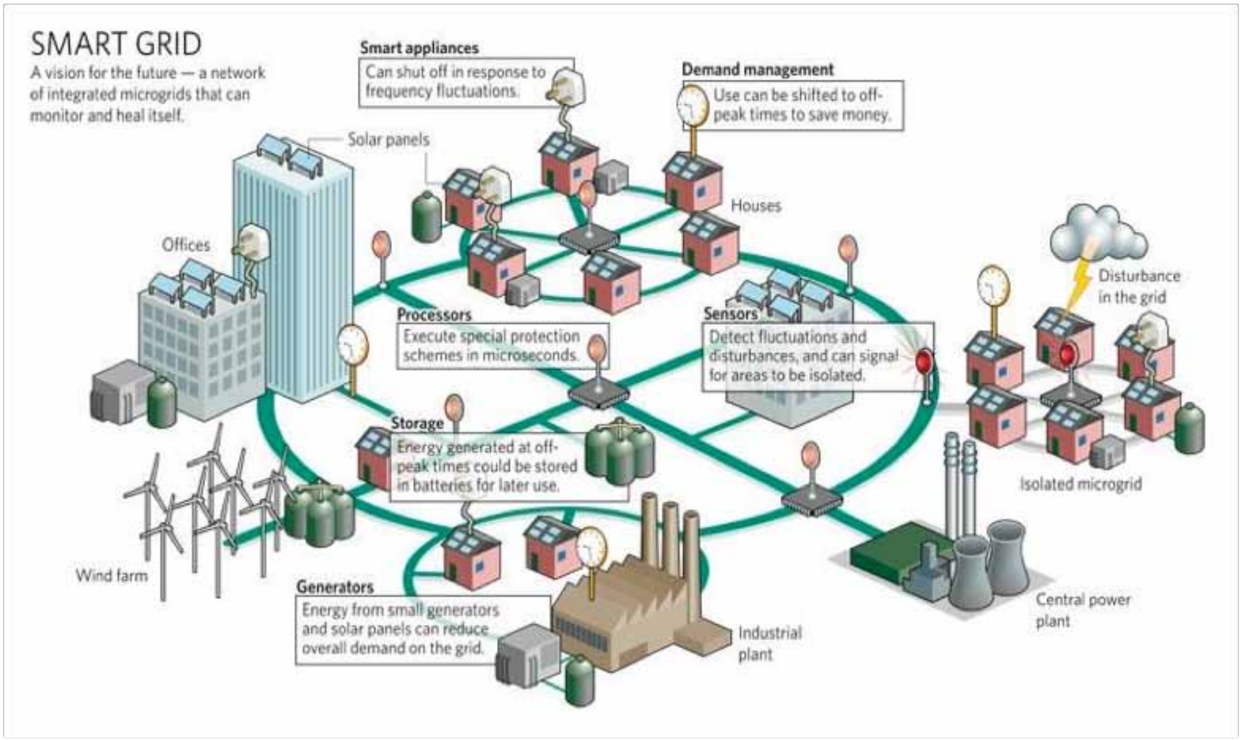


Figure 1. A Vision of the Smart Grid[1]

PART 1: GRID ARCHITECTURE

Background and Context

Background

The existing electrical transmission and distribution system in the U.S. uses technologies and strategies that are many decades old and includes limited use of digital communication and control technologies.[2] To address this aging infrastructure and to create a power system that meets the growing and changing needs of customers, a new concept of smart grid is introduced that uses new technologies to manage the generation and distribution of electricity more effectively, economically, and securely.

Major technical barriers to updating the nation's power system include developing an efficient power supply grid which can help solve other technical challenges, such as integrating distributed renewable-energy sources with the grid, managing transmission losses, addressing power-quality problems, and enhancing asset utilization. Without a smart grid, high penetration of intermittent renewable energy sources (i.e. wind or solar) may become increasingly difficult and expensive to manage.[3]

Context

At the residential level, devices which are in place now and are expected in the future have the ability to provide electric power support. Inverters which connect distributed generation such as solar panels, wind, and plug-in hybrid electric vehicles (PHEVs) to the grid are some examples. Such devices are not currently utilized extensively by the present power system. The integration of renewable energy sources with the present grid can be achieved by implementing better scheduling techniques, developing advanced storage devices, and building a stable power supply network.

The objective of this section is to point out key issues with the present power grid and to provide recommendations to support the modernization of the grid to maintain a reliable and secure infrastructure that can meet future load growth and achieve the characteristics of a smart grid.

Key Issues

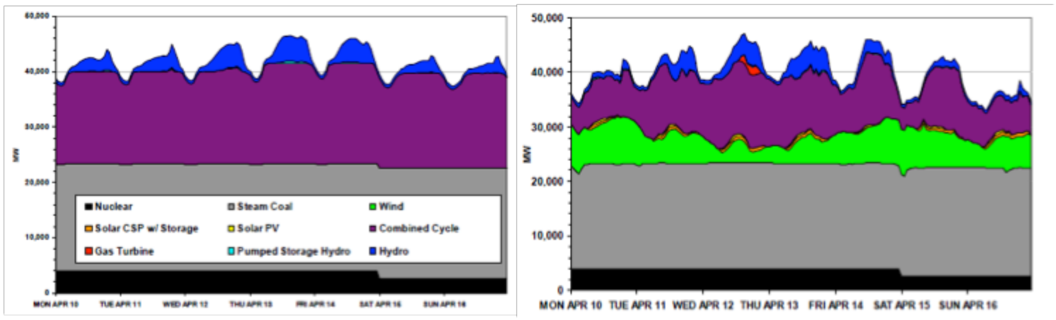
Most of the power generation sources today are centralized plants which produce pressurized, high-temperature steam to spin a turbine. Their boiler is heated by combusting coal or natural gas, or nuclear fission. The advantages of centralized plants are that they have low fuel costs and require fewer people to operate and maintain them, but there are a number of potential drawbacks to such a system. Some of drawbacks are the high level of dependence on fossil fuels, the environmental impact of greenhouse gases and other pollutants, and the necessity for continuous upgrading and replacing of transmission and distribution facilities. Most of these plants are located far from the load consumption centers. This necessitates long transmission lines which incur significant power losses. Nationwide, transmission and distribution losses were about 5% in 1970 and increased to 9.5% in 2001 due to higher utilization and more frequent congestion.[4]

> *"The variability of these energy sources is not a major problem so long as they are a small percentage of the total power available and are covered by the availability of spinning reserves. Storage can serve as a firming mechanism for renewable resources."*

Conventional Generators' Shortcomings Magnified with Increased Renewable Energy Penetration

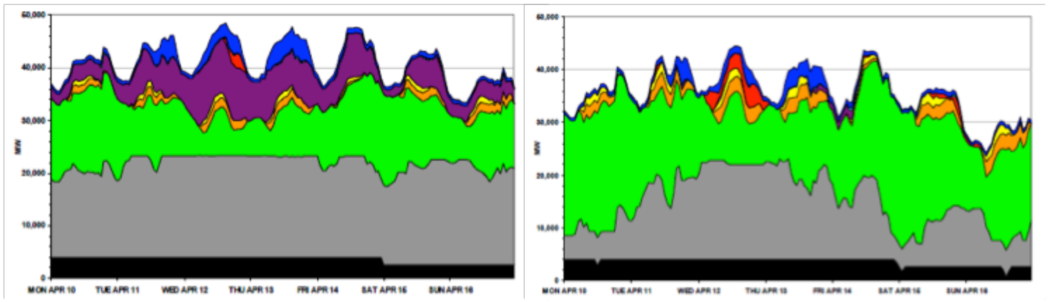
With the environmental concern of emissions from conventional fossil fuel power plants (i.e. coal, natural gas, oil) more efforts are undertaken to increase generation from renewable and clean energy sources like wind and solar. The conventional grid's use of coal and nuclear-fueled generators have shortcomings which are aggravated with the integration of renewable energy sources.

The power generated from wind turbines and solar photovoltaic (PV) is intermittent. When such systems are integrated with the conventional grid, the fluctuations in output power from the renewable sources need to be balanced by adjusting the generation at other plants. With higher penetration of wind, and PV power generation occasionally, there is a need to ramp base load plants. Such coal or nuclear plants are built to run at a fixed base load. Cycling increases maintenance costs and might lead to higher emissions rates. Figure 2[5] shows the impact of renewable energy integration on conventional base load power plants. It is evident from Figure 2 that the output generation of coal and nuclear plants is almost constant with no renewable energy sources in the system, but they need to cycle with increasing renewable penetration.



No renewable penetration

10% renewable penetration



20% renewable penetration

30% renewable penetration

Figure 2. Cycling of Coal-powered Generation Plants with Higher Renewable Energy penetration[5]

Recommendations

Although much research is still needed to overcome the issues with the present grid, a few key measures are stated below.

1) **Distributed Generation (DG)** is an approach that employs small-scale technologies to produce electricity close to the end users of power. Today's DG technologies often consist of renewable generators (i.e. solar PV, wind turbines, microturbines), and offer a number of potential benefits. In many cases, distributed generators can provide lower-cost electricity and higher power reliability and security with fewer environmental consequences than traditional bulk power generators.

The primary applications for distributed generation are[6]:

- *Combined heat and power (cogeneration) plants* increase the efficiency of on-site electricity generation by using the "waste heat" for existing thermal loads. These plants use a gas turbine or Stirling engine exhaust for a heating process. Many manufacturing facilities utilize cogeneration plants to supply electricity and heat to their electrical and thermal loads, respectively. Energy efficiency improvements of 20% are possible by capturing and harnessing this otherwise lost thermal energy.
- *Premium power production* reduces frequency variations, voltage transients, surges, dips, or other disruptions.

- *Back-up power* is used in the event of an outage, as a back-up to the electric grid.
- *Peak shaving* is the use of DG during times when electric use and demand charges are high.
- *Low-cost energy* is the use of distributed energy sources as primary power that is less expensive to produce locally than it is to purchase from electric utilities.

DG may provide the consumer with greater reliability, adequate power quality, and the possibility to participate in competitive electric power markets. DG also has the potential to mitigate overloaded transmission lines, control price fluctuations, strengthen energy security, and provide greater stability to the electricity grid.

2) DC Microgrids are another potential solution to reduce electric losses and to support distributed generation.

- The conventional electrical system in place today powers our electrical devices by AC mains. But as renewable technologies such as solar PV become more prevalent at a household level, DC microgrids could be a cheaper and more efficient alternative.

PV cells and many small scale renewables generate low voltage DC power. Often these generators require power invertors with transformer efficiencies of about 92% to supply power to AC circuits, though the power may ultimately be delivered to a DC device.

- A possible solution is to install a DC circuit network linking DC devices to DC power supplies.
- Such networks have not yet proliferated because of the higher costs to install a parallel set of circuits in buildings which are served by DC power. Also, at the transmissions level, higher electrical losses are associated with transmitting a fixed amount of power as low voltage DC rather than high voltage AC.

The proliferation of low power electronic devices and the potential for LEDs to reduce electrical loads by up to a factor of 10 for indoor and outdoor lighting makes the use of localized DC microgrids practical.[7]

3) Renewable Energy Integration is the path towards sustainability but the present electric grid is not suitably equipped to handle the increased use of renewable-based electrical generation. A few solutions are recommended to tackle those issues:

- Dynamic scheduling of dispatchable generation
- Consolidation of balancing areas
- New operational practices and economic curtailments
- Better use of flexible energy storage, including dispatchable hydro and pumped storage
- Plug-in hybrid electric vehicles (PHEV) with smart-charge controllers that can manage power demand and supply to the grid
- Price-responsive load balancing, including Demand-Side Management (DSM) and Demand Response (DR)
- Integration of wind forecasting into the control room

PART 2: THE EMERGING NEED FOR ENERGY STORAGE

The need for energy storage will increase as the amount of renewable energy supplying power to the grid increases. Utility-scale storage allows for the use of renewable power at more convenient times for overall grid efficiency as well as base-load plant efficiency. Local-scale storage can mitigate power fluctuations from solar PV units affected by clouds which might otherwise result in voltage drops. Smart grid communications technology will enable greater use and control of energy storage in both contexts, but only if planning of storage facilities occurs alongside the planning of the smart grid.

Background and Context

At the present time energy storage is not an important issue with respect to the smart grid; however, it will become much more important in the future as we introduce more renewable energy into the grid and optimize the power distribution system. Currently, storage of energy for the generation of electricity is largely used to exploit low-cost power generated from coal and nuclear power plants at times of low power consumption, typically at night. The stored energy is then used at times of peak energy use, typically in the afternoon, to displace the need for higher cost peaking power from sources such as gas-fired generators.

As the amount of renewable energy supplying power to the grid increases, the need for energy storage will also increase. This is because the availability of wind and solar energy are controlled by natural cycles that often do not match our needs for electrical energy. For example, no power is produced from solar cells at night or from wind when it is not blowing. If, for example, there is more wind power being generated than can be absorbed by the grid at night and only a little wind is blowing in the middle of the day, when it is needed, storage may be the most inexpensive and "green" way of having the necessary power when it is needed. Short-term storage plants can go online within a 60 Hz cycle (that is, 1 second) to serve the load for at least 10 minutes. Long-term storage plants go online within 6 to 10 minutes of the signal and can supply power to the grid for a few hours.

Storage may also be useful for handling occurrences where renewable-generated power plus the base load power from coal fired plants exceeds the current load. Utilities use wind power to meet Renewable Energy Standards and therefore endeavor to use their energy first, before base-load resources. The use of wind power can result in inefficient operation of base-load coal plants. As coal-fired plants are designed to operate at a fixed level varying the power output may lead to increased maintenance costs. Storing renewably-generated energy for use when there is a peak load rather than using the energy upon generation could mitigate this problem.

Distributed solar power presents another concern implicating usefulness of storage. As more distributed solar power is added to residences and businesses such that it becomes a significant fraction of total power, fluctuations can occur in local neighborhoods that lead to power flow both into and out of the neighborhood. Indeed, variations of about 70% may occur in the power from solar cells in periods of a few minutes when midday clouds pass over. Smart grid communications systems will be required to control these power fluctuations and may make it possible to locate storage in the neighborhood in order to control the charging and discharging cycles locally.

Advantages of Storage with the smart grid:

- It can be placed locally to improve reliability and efficiency.
  - › Local storage can be used to maintain local voltages during periods of high loads.
  - › It can be used to maintain power when faults occur closer to the main power plant.
  - › It can be charged at night when losses are low due to lower ambient temperatures and used to supply peak power at higher temperatures.

- Storage can be used to smooth the variations in wind and solar power.
- Storage can reduce the costs of integrating wind and solar power into the grid by mitigating inefficiencies of ramping base-load coal plants.

Disadvantages of Storage:

- Pumped hydroelectric power is the most efficient and lowest cost method for storing large amounts of energy. However, it requires large capital expenditures, long periods of time to construct, appropriate geography and geology, and is amortized over long periods of time.
- Battery systems at the present time are expensive to buy and to maintain.
- Compressed Air Energy Storage, provided that the air is compressed by renewable energy, can reduce the amount of natural gas required for a given amount of electrical energy by about two thirds. But there are a limited number of locations where the geology in Colorado is appropriate for underground compressed air storage and they are in the western part of the state at substantial distances from both the wind farms and the loads that are largely in eastern Colorado and along the front range.
- Storage associated with plug-in hybrid electric vehicles will require sophisticated controls systems to ensure that the charging occurs when the other loads are light and that the draw from the vehicle leaves enough energy in the battery to support the needs of the vehicle operator. Secondly, changes in the infrastructure will be required to support a significant number of plug-in hybrids.

Recommendations

- Storage should be considered as an alternative to gas-fired generators as a means of coping with the variability of wind and solar energy. It may be both the low-cost solution as well as the most flexible tool to accelerate a large amount of renewable energy generation in Colorado.
- Potential sites for energy storage should be considered as part of the state-wide plans for the development of the smart grid.

PART 3: MAXIMIZING GRID STABILITY

Higher penetrations of renewable energy will present new challenges for controlling frequency, voltage, and loads on the grid. Construction of short-term and long-term energy storage plants to alleviate the shortcomings of the traditionally-operated grid, use of "zigzag" transformers to balance loads at substations, and use of reactive DC-to-AC current-controlled inverters to control voltage at strategic points in the distribution system can all contribute to a stable smart grid.

Background and Context

The deployment of storage plants, as discussed in Part 2 of this section, necessitates frequent switching actions. These can cause flicker effects and imperfect synchronizations which will result in poor power quality on the grid if not mitigated.

Thus while the design and deployment of renewable and storage plants are important, their concerted operation of renewable energy generation, storage, and the grid is also critical and should be done first, before refining the individual components. This allows us to explore the approximate compatibility of all components involved prior to deployment, and can improve the efficiency and stability of the future grid. The critical functions we must consider are load balancing at the substation level, voltage control on the grid itself, and secure two-way communication between dispatch centers, renewable sources, and loads. Bulk generation plants rely on drooping frequency-load characteristics, which distribute additional load through reference set points provided by the utility's control center. Thus the load-sharing of present-day plants through drooping control will be replaced by connecting additional storage plants as the peak power of renewable plants changes as a function of time and not load.

Also, distributed generation sources feeding into the single-phase system in a residential community can produce more power than is used by the same community. Therefore, power would flow back to the substation. This could result in unbalanced load conditions which must be transformed to balanced loads at the substation. This balancing can be achieved by special transformers such as the "zigzag" type.

Grid stability, reliability, and security are important objectives for the operation of a future smart grid. All three go hand-in-hand and cannot be treated separately.

Recommendations

- Voltage control must be achieved with both conventional and renewable energy sources on the grid. Traditional grids use capacitors and synchronous condensers to maintain voltage control. The grid was designed for conventional sources with both their real and reactive power generation. To get solar energy sources on the AC grid, DC-to-AC inverters must be used. DC-to-AC current-controlled inverters have useful properties which allow them to operate near zero power factor to produce reactive power. Such inverters are advantageous because they can both supply or absorb reactive power only and do not require real power. In addition, they can be installed at strategic points within the distribution system. A major advantage is that these novel reactive power inverters do not participate in resonances, as capacitors do.
- Steady-state and transient stability is based on load-frequency and voltage control through the deployment of short and long-term energy storage facilities, demand-side management, load balancing networks, and harmonic power eliminators, which can compensate for the intermittency of renewable energy sources.
- Reliability can be augmented by two-way, digital, automatic communication/control between dispatch centers, generation facilities, and dispersed loads.
- Security of communication/control must be ensured to an acceptable level of risk and is likely to require encryption.

PART 4: CHALLENGES OF GRID INTEROPERABILITY

Smart grid network interoperability, the ability of diverse smart grid components to inter-operate, is one of the biggest challenges to deploying a successful smart grid system. The development and implementation of universal smart grid interoperability standards will help overcome this challenge and create a secure, economic, and efficient smart grid system.

Background and Context

To achieve network interoperability, universal smart grid compatibility standards must be defined and implemented. Connecting smart grid devices and components through a communicating network is a complex technical feat.

There are two major interoperability categories:[26]

1) Network interoperability: exchange of data between systems across a variety of networks.
2) Syntactic interoperability: data structure compatibility between different systems.

A number of organizations, listed below, are actively engaged in the development of interoperability standards.

The National Institute of Standards and Technology (NIST): Assigned by the Energy Independence and Security Act of 2007 to develop a framework that includes protocols and model standards for information management to achieve interoperability of smart grid devices and systems.

Smart Grid Interoperability Panel (SGIP): Supports NIST in the development of standards for smart grid. Serves as a forum to coordinate the development of standards and specifications by various organizations.

Interoperable Device Interface Specifications Association: Non-profit association established to maintain and promote publicly available technical interoperability specifications based on open standards and support their implementation in interoperable products.

UCA International Users Group: Not-for-profit organization assisting users and vendors in the deployment of standards for real-time applications for several industries with related requirements.

> *"The exchange of data between multiple devices is a complex process. Devices that fail to communicate successfully can cause wide-spread system failures. In terms of smart grid, this could mean anything from massive power failures to dangerous security breaches. Thus, it is of utmost importance to define universal smart grid interoperability standards."*

Key Issues and Recommendations

1) Interoperability of Smart Grid Technologies

Various companies are developing and deploying unique smart grid technologies that are incompatible with other smart grid technologies and systems.

Recommendation: Establish common ground rules of interoperability that utilities and smart grid technology manufacturers must follow.

2) Interoperability of Cyber-Systems

A key requirement of smart grid is successful interoperability of the cyber-systems used to manage the power system. Scalable and secure inter-organizational interaction is a major security and management issue.

Recommendation: Interoperability among disparate computer systems can only be achieved through the use of internationally-recognized communication and interface standards. The National Institute of Standards and Technology, in consultation with industry and other stakeholders, is currently creating cyber-security standards.

3) Smart Meter Interoperability

Smart meter products manufactured by different companies are frequently incompatible with respect to protocols for exchange of data, security measures, interaction with other parts of the grid, tariffs, and policies.

Recommendation: Develop a smart meter operational framework to enable all smart meters to operate in harmony.[14] In other words, develop standards for interoperability between all smart meter systems and products. When developing standards, financial hurdles should be kept in mind. For example, manufacturers and vendors cannot afford to make upgrades in order to comply with compatibility standards on short-time scales, especially with revenue-sensitive equipment such as meters. Additionally, smart meter technology is developing rapidly and costs can be expected to decrease and functionality and security can be expected to improve. Timing for installation of smart meters should take costs and their life expectancy into consideration.

4) Interoperability of Plug-in Hybrid Electric Vehicles and the Smart Grid System

The grid may not be able to meet the electrical demand of charging PHEVs on a large scale. In addition, if PHEVs are plugged into public outlets, advanced technology will be needed to determine whose account should be billed for vehicle charging.

Recommendation: Design the infrastructure to accommodate the potential need for large-scale charging of PHEVs and to identify vehicles for billing purposes.

5) Technology Obsolescence

As new smart grid technologies are developed, other technologies will become outdated, and require upgrades and even full-scale replacements. This could create unmanageable costs for utility companies

Recommendation: Require manufacturers and vendors of smart grid components to use open standards, like IP-based open standards, which avoid the need for full-scale replacements and technology obsolescence.

CONSUMER PRIVACY AND THE SMART GRID

Kevin Doran, Elias Quinn

ABSTRACT: *This chapter concerns the potential consumer privacy problem posed by the massive deployment of smart metering technologies and the collection of detailed information about the electricity consumption habits of millions of individuals. The potential problems and solutions are discussed. This chapter is composed of two sections: (1) Background and Context and (2) Recommendations.*

BACKGROUND AND CONTEXT

The essential innovation behind the smart grid is information—highly detailed electricity usage data communicated by and between the utility, the consumer, and in many instances, third-party vendors. However, while this information—and the extrapolations that can be made from it—is what enables the smart grid to be "smart," it is also what makes the smart grid so potentially invasive of individual privacy. Smart grid data is a double-edged sword. The sharper the blade in terms of informational granularity, the more it can be wielded to achieve both societal benefits, such as grid reliability and energy efficiency, and invasions of privacy. As a recent report by NIST puts it: "The major benefit provided by the smart grid, i.e. the ability to get richer data to and from customer meters and other electric devices, is also its Achilles' heel from a privacy viewpoint."

As utilities throughout the United States continue efforts to install advanced meters throughout their service territories, more and more raw data will be communicated from consumers to utilities. Of critical importance to privacy concerns is the fact that the types of highly detailed information that can be extracted from this raw data are also rapidly increasing. But just as more—and more detailed—data about home energy use is pouring into utilities, the information that can be gleaned from that raw data is growing ever higher in resolution. From an electricity usage profile, modern analytical techniques can identify use of specific appliances within the homes, and will in the foreseeable future be able to pinpoint exactly where within the home those appliances are located. The possibility for gleaning potentially private information from this data is truly staggering, including when a resident showers, watches TV, and how often she prefers microwave dinners to a three-pot meal. The richness and detail of the insights provided by this newly refined and individualized information is matched only by the number of potentially troublesome uses for such data, which range from the targeted and nefarious to the structural and discriminatory. Furthermore, energy use itself has become tied to judgments about an individual's social responsibility, and so, while data collection booms, intuitions about the private nature of that data may well be shifting to be more protective of its disclosure.

Electric utilities face new pressures that could conceivably drive them to look for new sources of revenue. Potential climate change legislation and other possible causes of operation-cost increases mean utilities may go looking for ways to cover the new costs. While the natural method to do so is via a rate pass-through, it is not the only method. Indeed, rate pass-throughs may find themselves subject to stronger resistance than usual in light of the general economic downturn and nation-wide concern over the economy. What's more, e-commerce has proven that collection and sale of personal information can be a lucrative endeavor. This confluence of forces may well push utilities toward more invasive behavior than they have previously engaged in.

In short, electric utilities are (or soon will be) collecting more information than they have in the past, and there may be an increasing market incentive to tailor this data as a commodity to sell on that market. Existing privacy protection imposed by state statutes may well be inadequate to prevent such behavior. For such potentially dramatic privacy consequences, the solution may be fairly simple. Amending PUC regulations to explicitly require the protection of this information and opt-in measures prior to the information's sale or disclosure could be formulated to answer much of the concern. Furthermore, PUC regulations across the country are being overhauled in response to shifting rate structures, driven by federal initiatives and economic realities of electricity generation. Thus, the solution could be developed and implemented in relatively short order.

While the reasons for collecting more and higher resolution energy usage data are compelling, and efforts on this front should not be hindered, it may be prudent to take a second look at how the collected data will be managed and protected.

A. Hidden in the Data

The data concerning an individual's energy use that is being collected now or in the foreseeable future holds implications for privacy in two ways. First, the meaning of the raw data itself is shifting as electricity consumption is increasingly paired with environmental impact and social responsibility. As energy usage comes to be viewed in a different light by the public at large, it may be that individuals will want to guard the information more, while utility companies will simultaneously start to gather more information and make it more readily available (at least to some). Second, the increasing resolution of the data, and its expanding scope, now make it possible to deduce far more from an individual's consumption information than what used to be the case. Indeed, algorithms can be devised to pinpoint, from an individual's power profile, when she watches TV, washes her clothes, cooks herself dinner, or takes a bath.

1) Reconstructing Daily Routines

The collection of information on electricity usage patterns is important for a myriad of reasons; ranging from the more or less benign reason of utility self-interest in operating efficiency, to the noble interests of mitigating environmental impacts and driving national energy security. However, the information collected for these purposes holds a good deal of information about individual consumers, information that may trigger some to call it private and grimace at the possibilities for its misuse. As intuitions surrounding privacy shift with the changing uses of data—and the growing abilities of those with access to it—privacy analyses must consider not only the static portrait of relevant technology and law, but engage their dynamic realities and look forward to the next act in the play.

Two research paths concerned with electricity consumption and load management are converging. The first of these is the empirical research and load monitoring carried out through the employment of devices such as non-intrusive appliance load monitors on single homes for the collection of population sample data. These devices allow electricity loads to be recorded once or even multiple times per second, providing very detailed information about a resident's electricity usage. Such devices and related research are important; they allow for both greater oversight (and so control) over the building's electricity usage and monitoring efficiency, as well as the development of extensive appliance load libraries, which can then be used to identify the load signals of specific appliances from within an aggregated load usage profile.

The second field of research pertinent to our discussion is the development of mathematical methods and use of artificial neural networks to glean detailed usage information from low-resolution interval data. With the rapid installation of millions of smart meters across the country, and the potential for tracking a person's electricity usage beyond the walls of her own home—through, for example, the tracking of PHEV charges—these research efforts and the soon to be expansive data set housed at an electric utility could be used to unveil the intimate details of millions of consumers' day-to-day lives.

As the interval of the data collected by smart meters decreases, thereby creating higher- and higher-resolution load profiles, and the ability to disaggregate low-resolution data specific appliance events increases, we move closer and closer to the potential that electricity usage data will be a one-stop-shop for peering into the private activities of residential customers.

2) Appliance Event Tracking and Profiling Electricity Profiles: Stepping into Private Spaces?

What are the risks of this potential disclosure? The table below attempts to illustrate these potential risks by presenting some questions to which electricity usage data collected within an advanced metering infrastructure could provide answers:

CONCERN TYPE	RELATED QUESTIONS ANSWERED BY DETAILED USAGE DATA
Nefarious Uses	• When are you usually away from home? • Is your household protected with an electronic alarm system? If so, how often do you arm it? • When do you usually shower (and so prompt a long draw from your water heater)?
Insurance Adjusting	• How often do you arrive home around the time the bars close? • How often do you get a full night's sleep versus drive sleep deprived? • How often are you late to work, or rushing to get there on time? Does the time it takes you to get from your home to your workplace require you to break the speed limit to get there? • Do you have a propensity for leaving appliances turned on, i.e. a curling iron or stove range, and leaving the house?
Targeted Marketing	• On what days and during what times do you watch TV? How much home time do you spend in front of your computer? • How often do you eat in? Do you tend to eat hot or cold breakfasts? What is the relative frequency of microwave dinners to three-pot feasts in your home? How often do you entertain? • Are any of the appliances in your household failing or operating below optimal efficiency? Do you own (and so presumably like) lots of gadgets? Do you use a laundromat, or do you have your own washer and dryer? • Are you a restless sleeper, getting up frequently throughout the night (and so likely turning on lights, etc.)?
Inquiries Regarding Disputed Issues	• In a custody battle, say: have you ever left your child home alone? If so, how often, and for how long? • In a worker's comp hearing: how is it, with your disabled back, you were able to turn on the TV in the upstairs of your home less than a minute after turning off the lights downstairs?
Inquiries Regarding Regulated Activities	• Alabama recently passed a tax provision requiring obese state employees to pay for their health insurance unless they actively work to reduce their body mass index. So: why haven't you used your treadmill at home any time in the last week? You clearly have not been out of the house and away from a computer or TV long enough for aerobic exercise.
Discrimination & Profiling	• Race and ethnicity•Non-traditional family typologies • Gender or sex • Age • Used to direct prosecutorial discretion or law enforcement investigation
Medical Questions	• Do clinically depressed or bipolar individuals have distinctive energy profiles? What about people with behavioral disorders? Could you tell if someone had not been taking their medication?

The concerns presented here fall into two broad categories: concerns about the leak or inadvertent disclosure of the information, and concerns regarding the systematic disclosure or sale of the information. This division helps to direct efforts at containing the potential problem, discussed later. The thrust of these concerns, though, is a concern about a probationary state, where individual activities are restrained for fear—not just of being caught doing something they should not have been doing—but of being put on the defensive for something they may not have done at all. This is the fear of becoming a false positive, either for illegal or embarrassing activities. Whether the fear is legitimate (and the likelihood of analytic methods resulting in false positive matches for the behavior investigated is high), or a specter (because the likelihood of the method identifying a false positive is low), the result is the same: people start ordering their daily lives as if they are being watched. This is precisely the scenario where information gathering itself becomes a form of surveillance.

> *"The major benefit provided by the smart grid, i.e. the ability to get richer data to and from customer meters and other electric devices, is also its Achilles' heel from a privacy viewpoint."*

B. (Lacking) Data Protections

A key question presented in any privacy discussion is whether a Constitutional protection attaches to the context of concern. Other authors have dealt squarely with Fourth Amendment concerns related to advanced metering infrastructure and high-resolution energy usage information. The basic lesson of these investigations is that interval data of electricity consumption appears to be in something of a no-man's-land under Supreme Court Fourth Amendment jurisprudence. On the one hand, the Court has upheld the sanctity of the home as the touchstone for privacy protection. Technology that effectively pierces the blinds, exposing information about activities inside the home, requires a warrant before it is employed. It would appear that electricity usage data, as it contains many intimate details about the in-home activities of consumers, allows investigators to see through walls into the home; thus, access to the information should be restricted to essentially a need-to-know basis. On the other hand, business records collected and kept by third parties enjoy far fewer privacy protections, the underlying theory being that consumers elected to transact with the business and to engage in activities open to observation by the public. Traditional electricity metering information has generally been treated as business records and so lies unprotected by the Fourth Amendment.

In addition to protections imposed by the Constitution, however, the collection of electricity consumption data occurs within a regulatory framework imposed, for the most part, by state legislators and public utility commissions. What follows is an examination of just how the existing regulatory framework will protect—or leave exposed—the consumption information obtained through smart meters. First, as Colorado will soon be home to the nation's first smart grid city, the State's relevant PUC regulations serve as a case study for the discussion. Next, other state regulatory structures are examined and compared to that of Colorado. Finally, some observations are made regarding smart metering and the European Union Data Protection Directive of 1995, which "establishes common rules for data protection among Member States of the European Union."[1]

1) The Colorado Case Study

Xcel Energy has announced it is developing a smart grid pilot project in Boulder, Colorado, which is to be the United States' first "smart grid city." As a part of the project, the utility will be collecting fifteen-minute interval data on Boulder residents through the installation of smart meters.

How, then, does Colorado's existing statutory scheme protect consumers against disclosure of this information?

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[1] DANIEL J. SOLOVE, MARC ROTENBERG, & PAUL M. SCHWARTZ, INFORMATION PRIVACY 900 (2006) (discussing the European Union Data Protection Directive of 1995, Directive 95/46/EC, [hereinafter "EU Data Directive"] ***available at*** http://ec.europa.eu/justice_home/fsj/privacy/law/index_en.htm (follow "HTML version" or PDF version" hyperlink)).

Colorado prohibits utilities from disclosing "personal information" to other parties.[2] Under Colorado's PUC regulations, personal information can only be disclosed with the signed consent of the affected customer authorizing "disclosure to the particular requestor."[3] This protection prevents utilities from requiring the signature of a sweeping consent to disclosure as a condition of connecting to the grid. Each specific request for personal information from the utility must be approved by the customer.

However, the definition of "personal information" confuses the matter rather than assuaging privacy concerns. In the first instance, "personal information" is defined broadly to mean "any individually identifiable information obtained by a regulated entity from a customer, from which judgments can be made regarding the customer's character, habits, avocations, finances, occupation, general reputation, credit, health, or any other personal characteristics."[4] As shown earlier, the interval data on electricity consumption soon to be collected across the country for millions of households may contain information from which judgments and conclusions can be made regarding very specific habits of conduct carried on within the privacy of the home. Thus, it would seem that individual energy profiles that include interval readings would fit nicely within the regulations' protection of "personal information."

But the definition does not stop there. In order to clarify its scope, the definition lists specific classes of information that are not to be considered "personal," and so are not subject to the consent disclosure restriction.[5] These include, *inter alia*, "information necessary for the billing and collection of amounts owed to a public utility or to a provider of service using the facilities of a public utility."[6] In the case of smart meter data, this may well prove to be an exception that swallows the rule. As rates may fluctuate throughout the day, it would certainly be valid to argue that interval data on electricity consumption is critical to billing processes: without the interval data, the argument would go, a customer's bill would likely be miscalculated. The argument has particular relevance because many of the reasons driving the collection of more detailed consumption information relate to ensuring efficiency—including economic efficiency—in electricity generation and distribution. If successful, this has long ranging implications for the privacy domain of residential consumers.

2) Other Regulatory Approaches.

Not all states have regulation like that of Colorado, under which interval data would land in legal limbo. For example, Connecticut's Department of Public Utility Control defines protected "customer information" as:

> customer-specific information which the electric distribution company or its predecessor electric company acquired or developed in the course of providing electric distribution services and includes, but is not limited to, *information that relates to the quantity, time of use, type and destination of electric service, information contained in electric service bills* and other data specific to an electric distribution company customer.[7]

Connecticut utilities can only freely disclose such "customer information," including information required for billing and load reporting, to their generation entities or affiliates.[8] All other disclosures require the utility to "receive prior affirmative written customer consent."[9] While these provisions appear well suited to handle the potential privacy problems surrounding the collection of usage data by smart meters, the language seems to have

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[2] 4 COLO. CODE. REGS. § 723-1-1104 [hereinafter "CCR § 1104]

[3] CCR § 1104(a), *supra* note 2.

[4] 4 COLO. CODE REGS. § 723-1-1004(t).

[5] *See* CCR § 1104, *supra* note 2.

[6] *See id.*

[7] CONN. DPUC Regs § 160224h-1(2) (emphasis added).

[8] CONN. DPUC Regs § 16-224h-4(a)(1). There are, however, some requirements placed on this disclosure process. See CONN. DPUC Regs § 16-224h-4(a)(3).

[9] CONN. DPUC Regs § 16-224h-4(a)(2).

been drafted with an eye toward regulating the disclosure and sale of customer lists in competitive electricity markets. The disparate focus in the context—a protection for utility secrets used for the protection of consumer private information—leaves a big question mark about how the provisions would be implemented if disclosure practices were challenged under them.

California's Code also suffers from contextual uncertainty and, like Colorado's provisions, leaves somewhat uncertain the level of protection for information collected by smart meters–– though more because of its patchwork structure than its substance.[10] At the outset, California Civil Code provides reasonably good protection of collected consumer information by effectively prohibiting non-anonymized data from being "distributed for commercial purposes, sold, or rented"[11] and requiring that businesses in possession of personal information about California residents "implement and maintain reasonable security procedures" to protect against inadvertent disclosure.[12] Furthermore, information no longer being used by the holder is to be destroyed or otherwise modified to "make it unreadable or undecipherable."[13] However, the tenor of these protections indicates that the real concern of California legislators was targeted advertising,[14] so it is unclear just how broadly they will stretch to cover the dissemination of smart meter data.

Under a section of California's Public Utility Code concerned with the implementation of a smart meter pilot program, the code provides: "To ensure customer privacy, unless specifically authorized by the customer, information based upon customer data may not be used for any commercial purpose."[15] However, as with Connecticut's provisions, "on the whole, the law [California's Public Utility Code] seems geared towards protecting the investor-owned utilities' data collections, including but not wholly composed of customer information, from adverse market consequences."[16]

Finally, California's treatment of utility-kept information for purposes of law enforcement further muddies the analysis of just how well protected the information is. California Penal Code section 1326.1 allows law enforcement agents to subpoena utility records, but later provides that "nothing in this section shall preclude the holder of the utility records from voluntarily disclosing information or providing records to law enforcement upon request."[17]

The discovery of regulatory difference does not necessarily coincide with the discovery of any real difference in practices between the various jurisdictions, nor does the finding of a hypothetical loophole mean that it is exploited. Best practices and utility codes of conduct may bridge the gap between some of these jurisdictions and so narrow the practical differences in information management, and also sure up seemingly flimsy regulatory protections.[18] However, whatever the current practices, concern over shifting practices due to the imposition of new business pressures is legitimate, and it may well be that weaker data protections are exploited once the potential for profit is recognized. It is also important to note here that Colorado—soon to be home to the first smart grid city in the nation—and California—whose utilities are currently deploying more smart meters than anywhere else in the country—are likely to be the first states in which the privacy battles take place. As both

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[10] For an excellent overview of the legal framework at issue in California, see P.A. SUBRAHMANYAM, et al., NETWORK SECURITY ARCHITECTURE FOR DEMAND RESPONSE/SENSOR NETWORKS 14 (2005, rev. 2006) (report for the Network Security Architecture for Demand Response/Sensor Networks project, CIEE Award No. DR-04-03A, B, WA No. DR-005, under CEC/CII Prime Contract No. 300-01-043, conducted by CyberKnowledge and the University of California at Berkeley) [hereinafter "CEC DR Security Report"], pp. 20–33, App'x A, ***available at*** http://www.ucop.edu/ciee/dretd/ (follow "Draft Final Report (pdf)" hyperlink).

[11] CAL. CIV. CODE § 1798.60.

[12] CAL. CIV. CODE § 1798.81.5.

[13] CAL. CIV. CODE § 1798.81.

[14] *See* CAL CIV. CODE § 1789.82 (obligations cued "if the business knows or reasonably should know that the third parties used the personal information for the third parties' direct marketing purposes"); CEC DR Security Report, *supra* note 10, at A-3 (discussing Cal. Civ. Code §§ 1798.83(a)(1), (e)(6)).

[15] CAL. PUC Code § 393(f)(7).

[16] CEC DR Security Report, *supra* note 10, at A-3.

[17] CAL. PENAL CODE § 1326.1(e).

[18] In California, for example, though the regulations do not apparently impose are requirement that enforcement officers obtain a subpoena to get at consumption information, "utilities may and often do refuse to release the records without a subpoena." CEC DR Security Report, *supra* note 10, at 25 n.t.

states have relatively weak protections, it is fair to ask whether we want them to set the early precedent for business behavior and privacy protection concerning advanced metering data.

3) Observations Regarding the European Union Data Protection Directive

In 1995, the countries of the EU adopted the European Union Data Protection Directive ("the Directive"), a common set of rules setting out data safeguards and standards of care.[19] The goal of protection outlined in the Directive is binding on EU countries, but the language itself is not. Each country is tasked with developing its own implementing legislation and it must be consistent with the standards set forth in the Directive.[20] However, examining the Directive's provisions offers some insight into how smart meter data may be considered and protected in Europe.

At the outset, Article 2(a) of the Directive defines "personal data" as "any information relating to an identified or identifiable natural person ("data subject"); an identifiable person is one who can be identified, directly or indirectly, in particular by reference to an identification number or to one or more factors specific to his physical, physiological, mental, economic, cultural or social identity."[21]

The categorization of "personal data" triggers several rights and obligations under the Directive. Article 6(1) requires that personal data (a) be "processed fairly and lawfully,"[22] (b) be "collected for a specified" purposes and not be further processed for other purposes,[23] (c) be merely adequate and not excessive for the purposes motivating its collection,[24] (d) be kept accurate,[25] and (e) be kept in a form allowing for identification for no longer than necessary.[26] Subsection (b) addresses the concerns raised earlier surrounding the systematic disclosure or sale of collected information: restrictions on further processing or use for other than the original purpose cut out the potential consumers of private information, like insurance companies and targeted advertising firms. Subsection (c) and (e) take steps toward protecting electricity consumers against inadvertent disclosure of the information to parties that may have nefarious intentions: information that contains no more detail than necessary and that must be scrubbed of its identifying information as soon as it is no longer needed helps to curb risks associated with the leak of such information.[27]

> *"It is also important to note here that Colorado—soon to be home to the first smart grid city in the nation—and California—whose utilities are currently deploying more smart meters than anywhere else in the country—are likely to be the first states in which the privacy battles take place."*

Thus, as with Colorado's PUC provisions,[28] the threshold definitions and general protections seem to provide ample room to protect the smart-metered electricity customer. While they do not offer perfect protection out of the box, they at least provide the skeletal structure to protect electricity consumers from privacy invasions. If combined with a system for aggregating and anonymizing the information, it seems that the Directive's provisions could be sufficient to guard against many of the

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[19] See INFORMATION PRIVACY, supra note 1, at 900.
[20] *See* id. at 901.
[21] EU Data Directive, *supra* note 1, art. 2(a).
[22] I*d*. art. 6(1)(a).
[23] I*d*. art. 6(1)(b).
[24] *Id*. art. 6(1)(c).
[25] *Id*. art. 6(1)(d).
[26] *Id*. art. 6(1)(e).
[27] Incidentally, the recommendations made to the California Energy Commission on the issue of privacy and security in demand response programs mirrors the principles in the EU Directive set forth here. *See* CEC DR Security Report, *supra* note 10, at 76–77.
[28] *See supra* Part IV.A.1.

concerns raised earlier in Part III.B.4.

However, like Colorado's PUC provisions, the Directive provides exceptions that may cover smart meter data:

> *Article 13* – Exemptions and restrictions
>
> 1) Member States may adopt legislative measures to restrict the scope of the obligations and rights provided for in Articles 6(1), 10, 11(1), 12 and 21 when such a restriction constitutes a necessary measure to safeguard:
>
> (a) national security;
>
> (b) defence [sic];
>
> (c) public security;
>
> (d) the prevention, investigation, detection and prosecution of criminal offences, or of breaches of ethics for regulated professions;
>
> (e) an important economic or financial interest of a Member State or of the European Union, including monetary, budgetary and taxation matters;
>
> (f) *a monitoring, inspection or regulatory function connected, even occasionally, with the exercise of official authority in cases referred to in (c), (d) and (e);*
>
> (g) the protection of the data subject or of the rights and freedoms of others.[29]

Electricity consumption information is already used to investigate marijuana growth and drug manufacture. As the resolution of electricity consumption information increases, it will only become more useful for such enforcement activities. While it turns on an interpretation of the term "occasionally," there is a good argument in any case that such usage data fits within Article 13(f) of the directive as at least occasionally connected with defense, public security, or criminal investigations.

If such an argument is successful, any protections afforded to electricity consumers by Article 6(1)(c) and (e) could potentially evaporate. Interested parties concerned with security and criminal investigations would most certainly argue they need to be able to examine historical usage records and, further, that highly detailed information can only lead to more accurate and efficient law enforcement. Thus, the data management obligations under Article 6(c) and (e) could fall away.

While the protections of 6(1)(b) may fare better, they can still be eroded somewhat (reasonably) in the name of law enforcement and defense. Where the data management obligations evaporate entirely if those management practices even *sometimes* stymie law enforcement efforts, disclosure restrictions that stymie law enforcement need only be adjusted on a case-by-case basis in order to facilitate the information need.

RECOMMENDATIONS[30]

Consumer privacy is a critical issue in the context of smart grid. The potential for data mining and acquiring intimate details about consumer behavior and lifestyle is a reality. These risks may lead to major privacy issues unless a deliberate and thoughtful approach is taken to protect consumer information. The Colorado PUC should consider what level of restriction should be made for accessing this data and considering the trade-offs for commercial gain and power system reductions in energy usage. However, this should not be a categorical ex

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[29] EU Data Directive, *supra* note 1, art. 13(1) (emphasis added).

[30] Many of these recommendations were derived from an early draft of California Senate Bill 837. Cal. Senate 837, 2009-2010 Reg. Sess. (2010), *available at* http://info.sen.ca.gov/pub/09-10/bill/sen/sb_0801-0850/sb_837_cfa_20100412_115534_sen_comm.html.

ante determination; rather, the trade-offs for improved reliability, safety, and disaster recovery should be carefully considered and weighed against individual privacy protection.

Information Ownership

- Metering and energy usage data should be considered the property of the customer, regardless of whether this data is kept by the customer, utility, or third party demand response service provider.
- Individual customer information must remain confidential.
- Individual customer information should be broadly defined as “energy or electrical usage information and billing and credit information about an individual, family, household, or residence.”
- Third party service provider (“service provider”) should be defined as “a person or corporation that is not an electrical corporation and who collects customer energy usage data and also provides equipment, software, or services that enable customers to manage or reduce their electricity usage.”

Information Disclosure

- Privacy legislation should not limit a customer’s ability to directly and voluntarily provide confidential information to a third party.
- Electrical and gas corporations, as well as demand response providers, should be prohibited from sharing a customer’s energy usage information with third parties unless the customer expressly authorizes the disclosure in writing (opt-in); additionally:
  - › Third parties should be required to acknowledge in writing that the customer information is confidential and cannot not be shared or utilized by any other person, corporation, or entity without the customer’s express written consent.
  - › Should the customer authorize the utility to release confidential historical information to a third party, the customer or third party should be required to pay any reasonable administrative costs due to such release.
  - › The customer’s written authorization for release of confidential information should automatically expire three years from the date of authorization.

Statement of Privacy and Security Principles

- Third party service providers and electrical and gas corporations that provide smart meter technology to customer residences should be required to adopt a “statement of privacy and security principles.”
- A mechanism for third party service providers to file a statement of privacy within six months of commencing services to customer residences should be considered.
- For corporations, there should be a requirement that the statement be filed with and approved by the appropriate jurisdictional authority within the utility service territory.
- As a recommendation, the privacy statement may contain some or all of the following stipulations:
  - › The customer has the right to transparency in information gathering and use; that is, the utility must provide customers with meaningful, conspicuous, and comprehensive notice pertaining to collection, use, dissemination, and maintenance of individual customer information.

- The customer has the right to participate in the process by which information about the customer is collected and used; the utility must establish a process that seeks a customer's consent for collection, use, dissemination, and maintenance of the information; the utility must provide a mechanism for customers to access and correct their information.
- The customer has the right to know why their information is being gathered, and the utility must tell the customer the purpose for which their information is being gathered.
- Individual information must only be used for the purposes for which it was collected and may be shared only for purposes that are consistent with the contractual or commercial purposes for which it was collected.
- The utility must maintain the value and integrity of individual information and ensure that the information is accurate, relevant, timely, and comprehensive; the utility must provide a mechanism by which the customer can easily and confidentially access and view their information and report any errors; the utility must rectify incorrect information that is challenged by the customer.
- The utility must maintain a secure information gathering system and must protect all information through proper security safeguards against risks of loss, unauthorized access or use, destruction, modification, or unintended or inappropriate disclosure.
- The utility must subject itself to auditing to verify and ensure compliance with its statement of principles
- The utility must adopt a work plan to properly implement its statement of privacy; the work plan must be filed with the Colorado PUC; the work plan must be approved by the Colorado PUC; once the work plan is approved, it must be made publicly available on the utility's website and must allow customers to make comments and inquiries.
- The utility must ensure that every applicable person (i.e. contractor, equipment supplier, software supplier) is aware of and agrees to follow the statement of principles and work plan.
- The utility must immediately notify the Colorado PUC of any violation of the work plan by any employee or any other person with access to the smart grid system.
- Demand response providers must speedily investigate and take corrective action to prevent any violation of the work plan.
- The Colorado PUC must ensure that every smart grid deployment plan includes testing and technology standards, and must take specified actions for service disconnections.

Legal Implications

- Consider having Public utilities develop an annual report made public and including the following information:
  - The number of federal and state warrants and the number of grand jury, civil, and administrative subpoenas. received by the utility in the past year that pertain to its customers.
  - The number and types of actions taken by the utility in response to each category of information request.
  - The number of customers whose utility records were produced.
  - The type of information disclosed about the utility's customers.
  - The total amount of money received by the utility to respond to each category of information request.
- Consider a requirement that the report be annually provided to a relevant governing body, such as:
  - An Office of Information Security and Privacy Protection, similar to the one instituted in California, that would be established in order to review these reports and address any information privacy issues that may.

  ensue; this Office should be established as either a stand-alone governing body or should function as a department within the Colorado PUC.
  - The Colorado Public Utilities Commission.
  - The Rural Electric Cooperative Governing Board.
  - The City Council of the respective municipal utility.

- The holder of utility records should be required to notify the customer of the applicable order to produce the requested records, unless the court orders otherwise; if the court orders otherwise, then the order should be required to include a statement of facts as to why providing notice to the customer would impede the investigation.

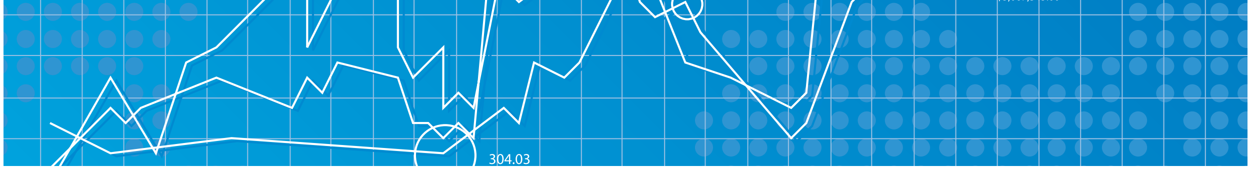
  - For the purposes of privacy legislation: *Personal information* should be defined as "any information that identifies or describes a *'family, household, or* residence'."

Conclusion

Advanced metering technology is being implemented across the country, and soon detailed information about millions of people's electricity use will be streaming into electric utilities. From this data, an intricate picture of a person's household activities can be reconstructed, and the resolution or detail of these reconstructions is likely to increase. Furthermore, the diffusion of plug-in hybrid electric vehicles through the market may expand the scope of electric consumption information beyond the home, making electricity usage information a one-stop-shop for anyone wanting to see a record of an individual's daily routine.

Here—as with all attempts at anticipating problems—the solution must involve, first and foremost, drawing attention to the potential privacy problem posed by the massive deployment of smart metering technologies and the collection of detailed information about the electricity consumption habits of millions of individuals. From there, efforts to devise potential solutions must progress in parallel paths, the first in search of a regulatory fix, the second a technological one. The first protects against the systematic misuse of collected information by utilities, despite new pressures on their profitability, by ensuring the databases are used only for their principle purposes: informing efficient electricity generation, distribution, and management. Such regulatory fixes are not difficult. Indeed, Connecticut's relevant regulations may already provide adequate protection against many of the "troubling implications" of this growing data set. Opt-in regulations are appropriate—at least in the short term—to protect consumers while the market for smart metering data develops and the full capabilities of those with access to that data are laid bare. As many states are taking a fresh look at their relevant regulations in connection with the restructuring of billing rates, swift action on this issue is both possible and easy.

In the final analysis, the privacy problem posed by smart metering is only a difficult one if the data is unleashed before consequences are fully considered, or ignored once unfortunate consequences are realized. But to ignore the potential for privacy invasions embodied by the collection of this information sets the stage for technology and commercial applications to define the boundaries of privacy before society has an opportunity to create adequate safeguards.



SMART GRID COST RECOVERY

Adam Reed, Stephen Chesterton

ABSTRACT: *This chapter concerns the potential consumer privacy problem posed by the massive deployment of smart metering technologies and the collection of detailed information about the electricity consumption habits of millions of individuals and companies. It covers three critical decision components of the cost recovery process with respect to smart grid investments by utilities. (1) The planning and oversight authority vested in the PUC is directly tied to cost recovery, meaning that cost recovery is likely to be a battleground for nearly any smart grid public policy decision, such as information privacy. (2) The determination of recoverable smart grid costs is likely to be contentious, because smart grid deployment costs may include more than simple technology costs and because estimating smart grid benefits has uncertainty. (3) The cost recovery mechanism used will affect the balance of risk to be borne by utilities and consumers with respect to possible future stranded costs.*

BACKGROUND AND CONTEXT

Utility recovery of smart grid costs have to date focused on recovery of costs related to the installation of Advanced Metering Infrastructure (AMI, commonly referred to as "smart meters," and also called "Advanced Metering Systems" (AMS) in some jurisdictions), a core smart grid component that some utilities have deployed because it offers a number of cost-savings measures, such as reduced truck rolls,[1] improved billing accuracy, reduced outages, and better load forecasting and management.[2,3] AMI provides the backbone of the distribution-side of the smart grid, because it allows two way communication between the utility and the consumer, be it a home, business, or industrial facility.[4] For instance, a typical smart meter might send data from the home to the utility regarding exact consumption over short time intervals, and the utility system might send data to the smart meter regarding the conditions of the electricity system, including marginal costs of generation as well as emission factors and load factors, at a given point in time. These functions allow a utility to bill a consumer for power consumption over a specific time interval, and thus to differentiate electricity prices according to different times of the day, when the utility's marginal costs of power production and delivery may differ.[5] Such "time of use" pricing might reward consumers who curtail consumption during high marginal cost periods, or, alternately, penalize consumers who do not.[6]

AMI deployment costs approximately $76 per meter, with an additional $125-150 per meter for communications

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[1] See Posting of Michael Graham Richard to Treehugger: A Discovery Company, http://www.treehugger.com/files/2009/11/smart-grids-fewer-utility-truckson-roads-reading-meters-truck-rolls.php (Nov. 9, 2009).

[2] See DAVID J. LEEDS, THE SMART GRID IN 2010: MARKET SEGMENTS, APPLICATIONS AND INDUSTRY PLAYERS 35–36 (2009), http://www.gtmresearch.com/report/smart-grid-in-2010.

[3] Note that cost recovery issues have also arisen in the interstate transmission context with respect to systems level smart grid components such as "synchrophasers," which improve system reliability through time-synchronized measurements of various system parameters which are sent to operators on the system. See NEIL L. LEVY ET AL., FERC GRANTS PACIFIC GAS AND ELECTRIC COMPANY'S PETITION IN FIRST APPLICATION OF POLICY ON RATE RECOVERY FOR SMART GRID INVESTMENTS 1-3 (2009), http://www.kslaw.com/Library/publication/ca123009.pdf. Transmission level smart grid costs would be recovered through increases in transmission rates. FERC has adopted an interim rate policy that allows cost recovery so long as the utility can show that the investment advances the goals of the Energy Independence and Security Act of 2007, does not adversely affect the reliability and security of the bulk-power system, minimizes stranded costs, and will provide feedback to the Department of Energy for further smart grid and interoperability standards development. Posting of Stacy Morford to SolveClimate, http://solveclimate.com/blog/20090717/ferc-adopts-smart-grid-policy-rules-raising-rates. Because these cost recovery issues are under federal jurisdiction, we will not discuss them further in this state-specific white paper.

[4] *See* Policy Statement, 74 Fed. Reg. 37,098 at 14 (July 16, 2009), available at http://www.ferc.gov/whats-new/comm-meet/2009/071609/E-3.pdf.

[5] *See*, e.g., RYAN HLEDIK & AHMAD FARUQUI, EVALUATING ALTERNATIVE DYNAMIC PRICING DESIGNS 3–7 (2008) http://www.brattle.com/_documents/UploadLibrary/Upload715.pdf.

[6] *See id.*

technology.[7] But the cost *savings* of AMI are more difficult to calculate because its efficacy—both in type and in number—is unproven. For example, Texas-based Oncor Electric Delivery Company's plan to install 3.4 million smart meters in North Texas by 2012 will cost approximately $686 million for equipment,[8] and $153 million in operations and maintenance; but Oncor also estimates savings of $176 million in meter reading savings and $28 million in ad valorem tax savings.[9] Another Texas utility, CenterPoint, estimates deployment costs at $847 million, including $639.6 million in capital investment and 207.9 million in operating and maintenance expenses from 2007 to 2021.[10] CenterPoint estimates savings of $120.6 million during the period in which its surcharge will be in effect.[11] A study by outside consultants for South Carolina-based Duke Energy estimates the average cost of a smart grid utility project at $775 million, but does not even attempt to estimate the value of cost savings and long-term benefits.[12]

> *"Chief among both utility and consumer concerns regarding the deployment of AMI is the question of who will bear the risks associated with the up-front costs for this new and unproven (at scale) technology."*

Chief among both utility and consumer concerns regarding the deployment of AMI is the question of who will bear the risks associated with the up-front costs for this new and unproven (at scale) technology. In order to understand those risks, we must understand how state public utility commissions (PUCs) regulate electric utilities and the rates that they charge to consumers. Utilities normally recover the costs of capital assets by including them in the "rate base," which is part of the regulator's determination of electricity rates that various classes of consumers pay.[13] PUCs set rates such that utilities can both cover fuel and operations costs and earn a satisfactory return on long-term investments so as to continue to attract capital.[14] In the case of a generation asset, such as a power plant, this is a conceptually straightforward matter. The utility forecasts its future demand, plans to build more assets to meet demand, then asks the state regulator for permission to include the asset in the rate base so as to recover the costs through consumer payment of rates.

AMI presents a more complicated set of factors for utility's financial planning and the surrounding activities of regulators. AMI provides opportunities for utilities to reduce costs (such as truck rolls) and shift demand so as to require less peak generating resources (sometimes called "load-shifting" or "load-flattening"). From this perspective, AMI is much like a generation asset. It is a capital investment that utilities purchase in order to satisfy demand. But *unlike* a generation asset, AMI attempts to reduce demand (over specific time periods) rather than increase supply. Because it is uncertain how consumers will respond to AMI and related smart grid functionality, it is difficult to predict how smart grid deployment will affect demand. Because it is unknown how much money AMI may save utilities, calculating how much to charge consumers—through rate changes or through more

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[7] PEW CENTER ON GLOBAL CLIMATE CHANGE, SMART GRID, http://www.pewclimate.org/technology/factsheet/SmartGrid (last visited May 19th, 2010).

[8] *See* Elizabeth Souder, *Oncor Begins Smart Meter Testing*, DALLAS MORNING NEWS, Mar. 10, 2010, available at http://www.dallasnews.com/sharedcontent/dws/bus/industries/energy/stories/DN-smartmeters_10bus.ART.State.Edition1.3ceedc2.html (last visited April 15, 2010).

[9] Public Utility Commission of Texas, *Docket No. 35718: Order on Oncor Electric Delivery Company LLC's Request for Approval of Advanced Metering System (AMS) Deployment and Request for AMS Surcharge*, at 6, §21, 22, Aug. 29, 2008, available at http://interchange.puc.state.tx.us/WebApp/Interchange/Documents/35718_102_594645.PDF [Hereafter PUC Oncor Order].

[10] Public Utility Commission of Texas, *Docket No. 35639: Order on Application of CenterPoint Energy Houston Electric, LLC for Approval of Deployment Plan and Request for Surcharge for an Advanced Metering System*, at 6, §26-27, Dec. 22, 2008, available at http://www.centerpointenergy.com/staticfiles/CNP/Common/SiteAssets/doc/AMS%20Final%20Order.pdf.

[11] *Id.* at 6, §8 [Hereafter PUC CenterPoint Order].

[12] *See* WILL MCNAMARA AND MATTHEW SMITH, DUKE ENERGY'S UTILITY OF THE FUTURE: DEVELOPING A SMART GRID REGULATORY STRATEGY ACROSS MULTI-STATE JURISDICTIONS 3 (2007).

[13] See FRED BOSSELMAN ET AL., ENERGY, ECONOMICS AND THE ENVIRONMENT 57-60, 78–79 (2d ed. 2006).

[14] *See id.* at 93.

immediate surcharges—is fraught with implicit judgments about risk and who ought to bear it.[15] The choice of the depreciation period for the technology also has a large impact on the cost savings numbers. Both Oncor and Centerpoint were allowed 7 year depreciation periods by the Texas PUC.[16]

A utility can shift the risks of AMI deployment to consumers by charging higher surcharges or rate increases up front. If the AMI fails to perform in reducing utility costs, the technology is at least paid off. If, on the other hand, the AMI proves effective, state regulators would reduce future rates to reflect the cost-savings. Some consumers bristle against the notion that they must shoulder the risk for a technology that is supposed to save the utility money. Consumers would likely prefer that the cost-savings benefits of AMI used in the initial calculation of rate increases or surcharges, because this will result in lower costs for them.[17] Below, we will provide a menu of cost recovery considerations regarding AMI, using other states as examples of the dynamic explained here.

KEY ISSUES

Google.org offers a comprehensive look at advanced metering deployment projects worldwide.[18] Given this excellent and continuously updated resource and our limited space in this White Paper, we have opted not to cover key issues and approaches on a state-by-state basis. Rather, we have distilled the multi-state research we have performed into a set of key issues, and provided relevant example citations to specific states where needed. This sub-section examines key issues and questions that arise in the context of smart metering deployments, and offers a menu of options that have been used in various jurisdictions with respect to each issue. The Key Recommendations subsection, *infra*, offers some normative guidance regarding which of the solutions listed here might work best in Colorado.

Planning and Oversight

State regulators generally have planning and oversight authority over AMI deployment projects, in order to ensure that AMI projects are reasonable and prudent expenses in the public interest, as they do with nearly all utility investments.[19] Without an initial regulatory determination that AMI deployment is reasonable and prudent, utilities cannot recover associated costs. PUC planning and oversight authority might entail approval or disapproval of the utility's deployment plan, enforcement of minimum functionality requirements for AMI devices, and receipt of regular progress reports from the utility regarding whether the project is on schedule and any problems encountered. The Texas PUC, for example, requires a utility's proposed advanced meters to have automated or remote meter reading, two-way communications, remote disconnection and reconnection capability, the capability to provide real-time access to customer usage data, and open standards and protocols that comply with nationally recognized nonproprietary standards. In California, AMI devices must support time-of-use or dynamic pricing, customer understanding of hourly usage and energy cost at different times of day, customer access to their usage data, applications for customer energy management, billing, and complaints,

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[15] *See* Bart Thielbar, ***Regulation and Smart Energy: Dealing with Uncertain Cost Recovery***, 6 ENERGYBIZ 54, 54-55 (Nov/Dec 2009), http://www.nxtbook.com/nxtbooks/energycentral/energybiz1109/index.php?startid=54#/56.

[16] PUC Oncor Order, ***supra*** n9 at 6, §23-24; PUC CenterPoint Order, supra n10 at 6, §30.

[17] Potential consumer wariness over surcharges and rate increases for AMI can be exacerbated by anecdotal accounts in many AMI deployment areas of smart meters dramatically over-charging consumers. Whether these anecdotal accounts reflect actual improved accuracy, unrelated weather changes that coincided with AMI deployment, or actual AMI malfunctions is unclear. Michael E. Young, ***Some Shocked by High Electric Bills Blame Oncor's 'Smart Meters***, DALLAS MORNING NEWS, Mar. 6, 2010, http://www.dallasnews.com/sharedcontent/dws/news/localnews/stories/DN-smart-meters_06.met.ART.State.Edition2.4c4df9f.html.

[18] GOOGLE MAPS, SMART METERING PROJECTS MAP (2010), http://maps.google.com/maps/ms?ie=UTF8&oe=UTF8&msa=0&msid=115519311058367534348.0000011362ac6d7d21187.

[19] See, e.g., Public Utility Commission of Texas, ***Project No. 31418: Order Adopting New §25.130 and Amendments to SS25.121, 25.123, 25.311, and 25.346 as Approved at the May 10, 2007 Open Meeting, available at*** http://interchange.puc.state.tx.us/WebApp/Interchange/application/dbapps/filings/pgSearch_Results.asp?TXT_CNTR_NO=31418&TXT_ITEM_NO=110 [hereinafter PUC Project 31418 Order].

applications to improve system reliability and efficiency, and load control communications technology.[20]

Additionally, some state legislatures are taking actions to address non-cost-recovery concerns—such as the protection of consumer privacy, customer ownership of consumption data, and 3rd party access to data and consumers—through the smart metering cost recovery process. California's legislature, for example, is considering a bill to impose data sharing restrictions on utilities as well as third-party service providers. Notably, the bill envisions the PUC's deployment oversight authority as the primary mechanism for enforcement of the restrictions. Thus, by virtue of its control over utility revenues, the cost recovery process is likely to become a battleground for a wider range of issues than simple cost-recovery.

AMI Deployment Cost Categories

Utilities and regulators considering cost recovery of AMI deployment must consider a variety of expense types related to the deployment effort. These include:

- **Hardware** – advanced meters and related components, communications infrastructure, installations, etc. Note that Texas allows utility surcharges "to reflect a deployment of advanced meters that is up to one-third of the electric utility's total meters over each calendar year, *regardless of the rate of actual AMS [sic] deployment*."[21]
- **Operations and Maintenance** – information technology usage and strategic planning services, repair and replacement of malfunctioning equipment.
- **Marketing and Education** – generating and maintaining customer support for smart grid deployment. This cost should not be underestimated. When consumers do not understand the benefits and purposes of smart meters, and this lack of understanding combines with technology glitches, dissatisfaction mounts.[22] Funding smart meters through customers requires actively managing customer attitudes, at least until the technology is proven.
- **Demand Destruction Compensation** – compensating utilities for lost sales resulting from consumer reductions in energy usage due to smart grid technology.[23] Utilities must receive enough revenue from electricity sales to meet their sunken capital costs, thus any reductions in the total quantity of electricity sold is dangerous to the utility's financial viability. Note that this phenomenon is distinct from smart grid enabled load management, which simply shifts consumption from one period of the day to another.
- **Low Income Customer Assistance Allocations** – customers already struggling to pay their electricity bills may require subsidization from other customer classes or from a state agency in order to handle higher bills from AMI deployment.
- **Legacy Meter Retirement** – some recently installed, non-smart meters may not yet be fully depreciated. A wide-scale deployment of AMI may require regulators to allow utilities accelerated depreciation of such equipment.[24]

Utilities and regulators must also consider the potential cost savings of smart grid discussed *supra* in the

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[20] *Id*. at 87-89, §25.130(g)(1).

[21] PUC Project 31418 Order at 94-95, §25.130(k)(3).

[22] Oncor customers in Texas voiced nearly immediate complaints about smart meters when they were deployed in late 2009, with hundreds of people claiming dramatic increases in their electric bills and citing malfunctioning meters. *See* Michael E. Young, *Some Shocked by High Electric Bills Blame Oncor's 'Smart Meters,'* DALLAS MORNING NEWS, Mar. 6, 2010, available at http://www.dallasnews.com/sharedcontent/dws/news/localnews/stories/DN-smartmeters_06.met.ART.State.Edition2.4c4df9f.html.

[23] Feedback to consumers from smart grid technology has been shown to result in energy use reductions of 5-15 percent for instantaneous feedback, and 0-10 percent for processed information provided after the fact. See Sarah Darby, Envtl. Change Inst., The Effectiveness of Feedback on Energy Consumption: A Review for DEFRA of the Literature on Metering, Billing and Direct Displays 3 (2006), http://www.eci.ox.ac.uk/research/energy/downloads/smart-metering-report.pdf.

[24] Idaho has taken this approach over its 2009-2011 AMI deployment period. *See* Schwartz, *supra* n21.

Background sub-section. These cost savings include:

- Reduced personnel and trucks needed for manual meter reading
- Improved billing accuracy
- Reduced outages
- Better load forecasting and management
- Enabling of greater utilization of renewable energy and other low-carbon generation assets (assuming a future domestic price on carbon emissions)[25]
- Integration of plug-in hybrid electric vehicles onto the grid as energy storage media as well as new sources of electricity demand.
- Revenue streams related to the sale of customer usage data.

Generally, these cost savings estimates should be subtracted from the initial costs of smart grid deployment in order to arrive at a net cost to be paid through rates, surcharges, or the like. Estimating cost savings, however, is complicated. As explained in section 7, it is uncertain how consumers will respond to efforts to manage load. Moreover, utilities run the risk that consumers interfacing with smart grid technology may reduce overall consumption rather than simply shift their time of use, resulting in reduced sales of electricity.[26] Utilities might make up the shortfall by selling customer usage information into data markets, but it is not at all clear that utilities have any interest in doing so.[27] Finally, the benefits of enabling low-carbon generation assets are unknown in the absence of a mandatory domestic carbon market.

The depreciation period chosen for new AMI installations will have a significant impact on the net cost estimate, because smart grid technology must be paid for in the near term, but accrues increasingly larger cost savings over the long term as more meters are deployed and utilities and consumers gain competence in using smart grid technologies. A depreciation period that is too short will underestimate the cost savings to the utility over the long run, and may overcharge consumers for AMI deployment.

Cost-Recovery Mechanisms and Implementation

Once the AMI deployment has been approved and its net cost determined, regulators must determine the mechanism by which the utility will recoup costs. A variety of options exist:

- **Trackers** – A tracker is a mechanism that allows the utility to record unpredictable costs that it has incurred. The utility will submit its tracked expenses to the regulator and be compensated over a fixed time period. Trackers are the most widely used cost-recovery mechanism for AMI deployment because they are flexible, allowing utilities to recover costs as they arise, rather than attempting to predict costs on an unfamiliar technology. They are generally implemented without a rate case, saving time.[28]

- **Surcharges** – A surcharge or "rider" is a PUC approved charge that is not incorporated into the utility's rate base. Surcharges are usually fixed charges that appear monthly on a customer's bill. Used by Texas and Oregon,[29] surcharges are the second most common cost-recovery mechanism for AMI, and tend to be determined through a marginal cost methodology, determining the additional cost of servicing a particular

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[25] *See,* e.g., David Talbot, *Lifeline for Renewable Power: Without a Radically Expanded and Smarter Electrical Grid, Wind and Solar Will Remain Niche Power Sources*, TECH. REV., Jan.–Feb. 2009, at 40, 44-47; see also Steven Andersen, Trial and Error in Texas, PUB. UTIL. FORT., Jan. 2009, at 28, 30, http://www.fortnightly.com/article.cfm?p_id=242 (describing technical and economic difficulties of managing highly variable wind energy sources on an electric grid).

[26] *See* Schwartz, *supra* n21.

[27] *See* ELIAS LEAKE QUINN, SMART METERING AND PRIVACY: EXISTING LAW AND COMPETING POLICIES, REPORT FOR THE COLORADO PUBLIC UTILITIES COMMISSION (2009), http://ssrn.com/abstract=1462285. Note that Idaho has mandated that utility revenues generated through the smart grid flow directly to consumers to offset rate increases from deployment. *See* Schwartz, *supra* n21.

[28] *See* MCNAMARA & SMITH, *supra* n12 at 4.

[29] *See* Schwartz, *supra* n21.

class of customer, then dividing the cost by the number of customers in the class.[30] If a rate case occurs while a surcharge is in effect, the surcharge-supported equipment is typically moved into the rate base and paid for through rates thereafter.

- **Electricity Rates** – AMI deployment costs may be recovered through the payment of retail electricity rates, as are most capital assets owned by utilities. The AMI deployment costs must be included in the utility's rate base through a rate case proceeding. Because rate cases occur infrequently, and can be contentious and time-consuming, this option does not provide most utilities with the up-front capital needed to deploy smart grid technology.[31] Of course, surcharge-based cost recovery strategies will eventually transition to inclusion in the rate base. Both Pennsylvania and Idaho allow AMI cost recovery through electricity rates.[32]
- **State Funding** – States might provide a direct grant for the deployment of smart grids, and charge the PUC with specific oversight responsibilities. Given Colorado's current budget situation, this does not appear a promising option. Were the state treasury in better shape, a fund, such as the oil & gas severance tax fund, could be used to offset some of the deployment costs of AMI.
- **Federal Funding** – The American Reinvestment and Recovery Act of 2009 (ARRA) provided approximately $4 billion in stimulus funds to smart grid deployment efforts.[33] Many of the Department of Energy programs funded through ARRA may receive more funding in future years. These funds can significantly reduce the costs of a smart grid deployment, and take pressure off of consumers who would otherwise pay the full cost.

RECOMMENDATIONS

Policy makers should think carefully about each stage of the smart grid cost recovery process outlined above:

- The planning and oversight stage of the cost recovery process provides valuable opportunities to address many of the issues raised elsewhere in this white paper. A failure to address those issues at the planning stage will make it very difficult for regulators to request changes from utilities later in the game.
- The cost determination stage is likely to be the most contentious, with utilities pressing for a maximum accounting of deployment costs and a conservative estimate of AMI-related cost savings. Electricity customers and their advocates will likely take the opposite position, minimizing deployment costs and estimating higher cost savings and benefits. Policy makers and regulators should strive to follow objective analysis and research regarding everything from the cost of components to the behavior of individual customers gazing at their home area network control panel while guarding against undue influence from utilities and/or customer advocates.
- The choice of a cost recovery mechanism will likely depend on the financial needs of the state and the utility, and also on the level of support for the technology. A tracker will provide the simplest and least cumbersome regulatory process to implement, but provides very little guidance to the utility and may result in wasted investments. A surcharge may be more difficult to implement but would require utilities to plan deployment in a more rigorous manner. Inclusion of AMI in the rate base is not recommended at this time, as the process will be lengthy and expensive, and a surcharge-based cost recovery strategy may be folded into the rate base at the next regularly-scheduled rate case, after the technology has (potentially) proven its worth.

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[30] *Id.*

[31] Ohio recently passed SB 221, which allows for a single-issue rate making specifically for the Distribution Infrastructure Modernization Plan. It includes incentives "for the utility's recovery of costs, including lost revenue, shared savings, and avoided costs, and a just and reasonable rate of return on such infrastructure modification." *Id*.

[32] *Id.*

[33] American Recovery and Reinvestment Act of 2009, Pub. L. No. 111-5 § 405, 123 Stat. 143 (2009) (amending Title XIII of the Energy Independence and Security Act of 2007); *see also* Department of Energy, Recovery Act Selections for Smart Grid Investment Grant Awards - By Category, http://www.energy.gov/recovery/smartgrid_maps/SGIGSelections_Category.pdf (listing grants awarded for smart grid projects).

COMMUNICATIONS ARCHITECTURE

Amit Kumar Barik

ABSTRACT: *This chapter presents an overview of smart grid Communications Architecture. It has two parts: (1) Background and Context and (2) Key Issues and Recommendations.*

BACKGROUND AND CONTEXT

Background

The existing communication infrastructure of the power grid in the U.S. is one of the oldest technologies being used today. Such electric grids are often referred to as "the world's biggest machines," implying that the grid's present architecture is a centralized topology (Little, 2009, para. 1). Furthermore, the grid's native communication architecture has a slow response to power grid operators (Hauser, Bakken & Bose, 2005).

There is no doubt that advancing communication technology for the power grid is one of the solutions for the energy problems that the U.S. is currently facing. In short, according to Timmer (2008), smart grids are the future power grids that allow utilities and other value-added service companies to communicate and control end-user electric devices. Incorporating the Internet's two-way communications architecture into the power grid to provide reliability, security, and efficiency is a major step in the right direction.

Context

It is well known that the computer communication architecture internationally has undergone rapid development in the past few decades. The Internet Protocol (IP), one of the biggest reasons for the Internet's success, is a network layer protocol that can run over any physical layer. According to the electrical industry, the smart grid should support plug & play devices, be based on open standards, and should be interoperable. IP supports all the previous-mentioned properties, making it the primary choice for smart grid communication architecture (Lobo et al., 2009).

Many utilities have their own distributed networks and their own applications running over it. For example, some utilities may use SCADA services over SDH technology, and others may run remote metering technology over PLC technology (Lobo et al., 2009). All such applications and physical layers can be supported by IP. This section discusses key issues currently present in the smart grid's communication architecture and also the recommendations that are necessary to correctly design a communication network over distributions networks present in smart grids.

KEY ISSUES

The current power grid infrastructure has a "hub-and-spoke" or centralized architecture, which consists of individual substations as the spokes and control centers as the hubs (Hauser et al., 2005). This approach is not scalable and is therefore vulnerable to management issues, given its large systemic nature. This also causes the wide-area control model to react very slowly (Hauser et al., 2005). For example, even though today's intelligent electronic devices can gather useful information at the substations, such vital information cannot be distributed effectively beyond the substations due to the current communication architecture (Hauser et al., 2005). The current communication infrastructure is not a solution to the long-term needs of the power grid.

Another issue is the need for integration of standards across traditional operating domains (Hughes, 2006). This is a clear issue of interoperability. It is well known that interoperability is required for the growth of the electric system so that new and old technologies alike can simultaneously operate together in an automated and integrated electric infrastructure (*GridWise*™, 2005). According to FERC (2005) and Hughes (2005), interoperability is difficult to achieve because of the following issues:

1) Increased complexity of the electrical and information systems.
2) Scalability issues due to the current communication architecture present for power grids.
3) Cyber security.
4) New investment is limited.

Apart from this, today's various grid communication infrastructures are inflexible to support new or different services. This hinders the growth of a utility company (Lobo et al., 2008). In other words, if new applications or services are developed and deployed over the current communication system, it is either going to be very costly or pragmatically impossible. For example, wireless communication systems do not support PLC technology (Lobo et al., 2008).

One of the issues discussed by IETF (2009) is that of the co-existence of IP suite with existing protocols suites. For example, it is going to be difficult for utility specific protocol suites (like ANSI C12.22, IEC 61850, DNP3, etc.) to integrate with the IP suite (*The Role*, 2009). Other issues that are important and should be considered are that of adopting IPv6 for making smart grid scalable and secured (The Role, 2009). Lastly, if one wishes to use IP as a unified communication protocol suite for the smart grid system, it will be challenging to fully extend this suite from customer end to the power generation end (*The Role,* 2009).

RECOMMENDATIONS

The key solutions mentioned below are specifically for the issues mentioned above and are focused on solving the problems of the communication architecture of the smart grid.

- Considering the issue of "hub-and-spoke" architecture which is the primary cause of most of the issues mentioned above, a flexible communication architecture can be used to achieve a decentralized smart grid communication architecture. GridStat is one example of a communication architecture for power grids which is based on middleware framework that makes programming of power grid applications better (Washington State University, 2005). Due to its middleware characteristics which provide higher application program interface than sockets, control and monitoring applications can be implemented easily. This flexibility, quality of service, and decentralized architecture allow the communication system to provide further services to the grid (Hauser et al., 2005). It is recommended that a power grid infrastructure be deployed with GridStat.

Interoperability issues can be solved only if a set of rules and regulations are followed to achieve tight integration. Hughes (2005) and FERC (2005) have published certain rules and recommendations that should be followed to achieve interoperability.

- The boundaries of grid communication architecture should be broader than the ones present in an existing, traditional utility. The future architecture should have a scope that not only includes the revenue meters or power operations, but also spans across consumer-end equipments and substations (Hughes, 2006).

- The architecture should mainly account for only those applications that cross the traditional boundaries and have architectural significance (Hughes, 2006).
- Develop a general understanding of interoperability at several levels (*GridWise*™, 2005). Once all the parties have a clear understanding of the interoperability issues, which may be achieved by defining and publishing standards, only then can all the parties reach common goals (*GridWise*™, 2005).
- According to FERC, once the process of "path forward"—the steps to achieve interoperability—has begun, the progress of this process should be measured and recorded (2005).

Application Interoperability

- Open Connecivity protocol is tailor-made protocol for data interoperability and is therefore recommended. (Kok & Kepware, 2010)

IP is the preferred network layer protocol that should be considered for any end-to-end connectivity of smart grid devices. For those communication infrastructures that support only specific services, IP is the perfect solution as it can run over any physical layer (Lobo et al., 2008). For example, the newly developed "Open Smart Grid Communications Architecture" by Verizon Wireless and Ambient Corporation uses private IP clouds for connectivity (2010). It is recommended that the IP network utilize IPv6 addresses and should span across the whole spectrum of smart grid infrastructure. This will allow any infrastructure to support new services. IPv6 addressing is preferred for the reason being that it can support many more devices than IPv4 without losing any network transparency.

Furthermore, new or unsupported services can achieve end-to-end connectivity with the help of SIP (Session Initiation Protocol), an application layer protocol. It is highly recommended that SIP be used for smart grid end devices connectivity because of the following reasons:

- SIP supports all the kinds of communications needed by smart grid devices (DiAdamo, 2009).
- SIP runs over the IP network layer. This makes SIP independent of any underneath physical network (DiAdamo, 2009).
- SIP is secure, scalable, reliable, and mobile (DiAdamo, 2009). For example, SIP can be used by electric cars.

The issue of co-existence of the IP suite with other standards and also the challenge of making the IP a unified communication protocol are part of interoperability issues which can be dealt with by the above recommendations. Apart from this, there is still the last challenge of adopting IPv6 for smart grid end-to-end connectivity.

ELECTRIC TRANSPORTATION

Puneet Pasrich, Professor Dragan Maksimovic

ABSTRACT: *This chapter focuses on plug-in hybrid electric vehicles and pure electric vehicles, their relative strengths and weaknesses, and highlights emerging technologies that have the potential to define the future of transportation. A large-scale deployment of PHEVs and EVs will transform the light-duty automotive market. It will reduce air pollutants and carbon dioxide emissions and increase profits for electric utility companies provided the deployment is able to incentivize off-peak charging and integration within the upcoming smart grid system. This chapter is composed of three sections: (1) Introduction, (2) Background and Context, and (3) Recommendations.*

INTRODUCTION

A large-scale deployment of plug-in hybrid electric vehicles (PHEVs) and pure electric vehicles (EVs) will transform the automotive market, reduce air pollutants and carbon dioxide emissions, and increase profits for electric utility companies, provided the deployment is able to incentivize off-peak charging and integration within the upcoming smart grid system. A significant increase of PHEVs on the road will provide utilities the opportunity to optimize the use of both existing base load plants and transmission grid infrastructure. PHEVs and EVs could reduce oil consumption by up to 60% by 2050 and could offer opportunities for substantial reductions in green house gas emissions, especially when combined with a wider penetration of renewable sources in the electricity generation mix.

Barriers include cost premiums associated with batteries and charging infrastructure, as well as public acceptance of the paradigm shift to plugging in the vehicles routinely. Federal and state policies and directives will be key to accelerate the market penetration of PHEVs and EVs. Specific recommendations include fleet purchases of PHEVs and EVs by state and local governments, incentives to consumers and businesses to offset the cost premiums of PHEVs and its charging infrastructure, and support for public education and awareness programs. Utilities, the automotive industry, and research institutions should collaborate to establish standards that effectively utilize managed charging programs that would empower PHEV and EV users while also benefitting the electric power grid.

BACKGROUND AND CONTEXT

Transportation accounts for 28% of the total energy consumption in the U.S. The vast majority (93%) of this energy used in transportation comes from petroleum products: gasoline (62%), diesel (22%), and jet fuel (9%). Light-duty vehicles (cars and light trucks) consume 60% of the energy used in transportation, while commercial vehicles (23%) and mass transit (17%) account for the rest. The U.S. transportation sector accounts for 70% of petroleum consumption and more than 33% of greenhouse gas emissions. Because of concerns about energy security, fuel costs, and emissions, there is a push to reduce the dependence on oil as the primary source of energy for transportation in two directions:

1) *Increasing the fuel economy* or gas mileage (mpg) of vehicles, and

2) *Displacing petroleum* with alternative fuels.

Hybrid electric vehicles (HEVs) combine gasoline engines with electric motors to improve gas mileage. Automobile manufacturers have made significant investments over the last 20 years to produce today's high-mileage HEVs, such as the Toyota Prius and Ford Escape. It is important to note that HEVs are not alternative fuel vehicles— the primary source of energy is still petroleum; nonetheless, the petroleum is used much more efficiently. In contrast, a goal of emerging alternative fuel vehicle technologies is to displace petroleum as the primary energy source. Of particular interest in this chapter are "plug-in" vehicles that, at least in part, run on electricity from the electric utility grid.

Electric Vehicles and Plug-in Hybrid Electric Vehicles

The propulsion technology in PHEVs is very similar to HEVs except that PHEVs have significantly larger batteries which are charged from the grid when the vehicle is plugged into an electricity outlet. The energy stored in the battery can then be used to propel the vehicle for a certain number of miles called the "all-electric range" (AER) without needing to use gasoline at all. For example, the Chevrolet Volt (a mid-size car expected to be available on the U.S. market in 2011) with an AER of 40 miles is a PHEV-40. On trips longer than the AER, a PHEV employs the gasoline engine to operate as a HEV. A considerable advantage of the PHEV is its ability to charge its batteries while still having the capacity to drive away at "a moment's notice," with gasoline powering the internal combustion engine if necessary.

While no automobile manufacturers offer any PHEV models today (though it is expected that some models will be introduced next year), HEVs have been converted to PHEVs by enthusiasts and companies since the late 1990s. The movement to convert HEVs to PHEVs caught on following the initial efforts of CalCars, a non-profit start-up based in Palo Alto, CA. This organization was the first to perform a PHEV conversion of the Toyota Prius in September 2004, and continues to help commercialize PHEVs by developing technologies and promoting public policy. Today, there are a number of PHEV conversion companies. They typically replace the original equipment manufacturer batteries with a higher energy density battery pack, and replace the battery management system and integrate it with the vehicle electronics.

> *"Further, PHEVs and EVs could reduce oil consumption by up to 60% by 2050 and could offer opportunities for substantial reductions in green house gas emissions, especially when combined with a wider penetration of renewable sources in the electricity generation mix."*

Pure electric vehicles (EVs), also known as battery electric vehicles (BEVs), have no gasoline engines or fuel tanks at all and run on electricity at all times. The driving range of EVs is determined by the size of the battery energy storage. Notable examples of EVs are the high-end Tesla Motors Roadster, which has been commercially available since 2008, and the Nissan LEAF, expected to be available by the end of 2010.

Electric Range, Battery Size, and Charging Issues

The all-electric range of PHEVs is an important factor to consider: a PHEV with a larger AER is more successful in displacing oil as the primary energy source. However, a larger AER also requires a larger battery energy storage which in turn increases the cost of the vehicle. A mid-size PHEV requires 0.25 kWh of electricity per mile. So, a mid-size PHEV-40 requires about 10 kWh of *usable* battery energy storage. Taking into account current battery technology limitations, the vehicle needs 15 kWh of *total* energy storage capacity. Based on 2010 Lithium-Ion battery technology, costs of $500 - 1,000 per kWh make it clear that the battery adds a significant cost premium to the vehicle cost.

Different car manufacturers are coming up with PHEVs or EVs that have significantly different battery sizes. For example, the Toyota Prius PHEV, expected to be available on the market in 2011, has small usable battery energy storage of 4 kWh while the Tesla Motors Roadster, a high-end EV, has a 12-fold-larger 50 kWh battery. In the rest of this chapter, we assume that an average plug-in vehicle will have a PHEV-40 battery of 10 kWh.

There are several options for charging a PHEV or an EV from the electric utility grid. These options have been codified by the U.S. National Electrical Code as Level 1, 2, and 3. Level 1 charging corresponds to plugging the vehicle into a standard, commonly available plug (120 V, 15 A circuit, typical charging power of 1.4 kW). Assuming Level 1 charging from a standard outlet is used, a PHEV-40 is fully charged in 7-10 hours. Level 2 charging requires a less commonly available circuit (208-240 V, 12-80 A, typical charging power of 6.6 kW), which is on a charging station equipped with a cable and a connector standardized by the Society of Automotive Engineers (SAE J1772). This is comparable to the power consumption of central air-conditioning units, clothes dryers, or electric ovens. With Level 2 charging, a PHEV-40 can be fully charged in 1.5-2.5 hours. Level 3 charging based on a more specialized DC charging infrastructure, which is still under standards development, could provide a full recharge within a fraction of an hour.

As PHEVs and EVs are introduced into the market, it can be expected that Level 1 charging, which is readily available, will be widely used at first. Future Level 2 charging, which requires an electrician to install the appropriate hardware, may be justified by the decrease in charging time. Nevertheless, Level 2 charging stations at work or public locations will require infrastructure investments. Thus, as PHEV penetration increases, it is expected that Level 3 charging technology will eventually become available at dedicated charging stations.

Plug-In Vehicles: The Emerging Smart Grid Partner

The average U.S. household consumes 600-800 kWh of electricity per month. A PHEV-40 fully charged each weekday would add 200 kWh monthly, thus increasing the overall household consumption by 25-33%. In the state of Colorado, there are presently about 3.2 million light-duty vehicles. Assuming PHEVs replace 10% of these vehicles, the overall electricity demand in Colorado would increase by less than 2%. The relatively small increase in overall electricity demand implies that significant penetration of PHEVs, together with the corresponding displacement of oil as the primary source of energy for transportation, could be accommodated by the present day electric power grid with *existing generation capacity*[1-4]. According to the DOE's Office of Energy Efficiency and Renewable Energy, the idle capacity of today's electric grid could supply 73% (158 million vehicles) of the nation's vehicles' energy needs. This conclusion, however, ignores the more complicated effects of PHEVs on the electric power grid, including the potential for significant increases in peak power demand.

Consider, for instance, the case of *unmanaged charging*—i.e., where a PHEV is charged up as soon as it is plugged into an electric power outlet. This case corresponds to the present-day situation with no smart grid or energy management technologies deployed at the household level. Today's system peaks in late afternoon hours on hot summer days when air-conditioning units are on. If PHEVs are plugged in at the same time, there is potential for significant increases in peak power demands. This will present challenges to the electric power grid by adding even more stress on distribution transformers and adding the need for peaking generation units. This is why various *managed charging scenarios* are considered in the context of at-home energy management and utility-wide smart grid technologies.[5] In a basic managed charging scenario, PHEV charging is performed at more opportune times, e.g. at night, when the overall demand is considerably reduced and when the cost of electricity is lower. Such managed charging scenarios, which fall into the category of demand response technologies, could lead to significant benefits for consumers and utilities. For consumers, managed charging will reduce the cost of electricity for PHEV charging; for utilities, managed charging will eliminate the need for additional peaking generation capacity.

There are a number of additional benefits that utilities could enjoy with the widespread use of PHEVs or EVs combined with a smart grid or time-of-day-based cost structure. Pricing electricity more cheaply at night allows the utility to sell electricity from their lowest cost generator to the PHEV owner in order to recharge the batteries. Millions of PHEVs can also support the deployment of more wind farms, as any excess generation could be directed by smart grid systems into PHEV batteries. A smart charger could control the specific timing of each PHEV charging system to consume any bursts of wind-generated electricity by responding to its associated pricing signals.

In the event of a power outage or if the instantaneous cost of electricity is above a given threshold, the PHEV's battery can be used as a local generator. PHEVs have a capacity of 4-15 kWh, which can be used as the owner's battery backup system to power her home or sell to her employer if the price is adequate. Once again, a Vehicle-to-Home (V2H) transfer would rely on smart grid implementation to provide the critical pricing information for decision-making. Likewise, the utility itself might want to buy the stored electricity in a fleet of PHEVs to prevent having to purchase power from another utility during peak demands. The utility could also be in need of spinning reserves or reactive power. These V2G services could be purchased from the PHEVs instead of a competitor at favorable rates.

Another strategy that would ultimately benefit utilities is the large-scale purchase of PHEVs for their own fleets. Each utility could introduce EVs annually on normal vehicle replacement schedules to update their fleet. This allows even more control to use V2G capabilities, charging scheduling, and lower operational costs. A third strategy could entail the utility purchasing the battery and leasing it back to each independent PHEV owner. As part of the agreement, the utility could draw upon each EV's battery pack as needed to offset any load spikes or congestion relief. If needed, the utility could pay premium rates for the energy depleted from the PHEV battery.

Oil Displacement

Since the transportation sector currently accounts for 70% of petroleum consumption, a major benefit of transportation vehicle electrification could be a reduction in dependence on oil. As noted in a 2007 study by the Electric Power Research Institute (EPRI), PHEV-40 could reduce average gasoline consumption by 50% for the U.S. because the majority of daily driving trips in the U.S. are shorter than 40 miles.[1] However, the overall effect on petroleum consumption will greatly depend on the PHEV penetration rate.

Efficiency improvements alone, such as HEVs and other technologies, could result in a 40% reduction in gasoline consumption by 2050. Furthermore, in all scenarios considered, the oil-displacement effects are relatively minor until after 2020, because it takes many years for a sufficient number of new vehicles to penetrate the market. In any case, a long-term perspective must be adopted in policy planning because there are no viable short-term remedies for reducing oil dependence in the transportation sector.

Environmental Effects

When encouraging the public to purchase PHEVs by highlighting the environmental benefits of driving a PHEV, one could present the following data: The Toyota Prius HEV emits 80g of CO_2 per mile from the tail pipe, while a PHEV driven in electric-only mode has an effective emission rate of 28g of CO_2 per mile (when powered by electricity generated from a coal-burning power plant). A PHEV owner, who drives an average of 15,000 miles per year, could reduce CO_2 emissions by up to 2,000 kg. This represents 10% of the annual U.S. average CO_2 emissions per capita.

A PHEV must be charged, and the emissions displaced to an electricity generating plant, for it to run completely without gasoline. Despite the environmental disadvantages of coal power, there are two PHEV benefits. First, automobile-based tailpipe emissions can be moved to base-load plants and the associated smokestacks, where it is cheaper to clean up. This displacement allows for the ability to regulate, monitor, or capture emissions from a generating power plant. Since air quality regulations are more stringent for power plants than for automobile emissions, particles ($PM_{2.5}$ and PM_{10}) and ozone precursors (NO_x) are scrubbed in the smokestack. Also, the sequestration of CO_2 from large point sources, such as power plants, is an attractive avenue for climate change mitigation. The second benefit is that a large fraction of air pollution is shifted from urban areas to areas downwind of generating plants. This provides health benefits to people living in urban areas, because tail-pipe emissions are usually discharged in densely populated areas. Furthermore, with an increase in renewable sources of electricity there will be additional benefits, such as emission-free electricity.

Cost and Acceptance Challenges

Unfortunately, there are significant barriers to the expansion of the PHEV market. Current conversion prices range between $15,000 and $30,000 per vehicle. At these prices, the people who purchase PHEVs are paying a premium to be among the first to drive the world's cleanest extended-range vehicles. Early PHEV purchasers will also bear a large fraction of the cost for Lithium-Ion batteries, and the R&D aimed at redesigning battery management systems. The conversion companies themselves are not gaining a windfall profits because of the high conversion costs. At today's prices, PHEV conversion payback comes after 1,000,000 miles, assuming the lifetime of one battery set is estimated to be 100,000 miles.

In the next few years the major automobile manufacturers could capitalize on these opportunities by offering a PHEV option for an additional $3,000 to $5,000 to their HEV line. With mass-market production, it is expected that the cost of batteries will decrease. At that point, PHEV conversion companies will continue to upgrade existing HEVs as battery pack prices continue to drop.

> *"In the event of a power outage or if the instantaneous cost of electricity is above a given threshold, the PHEV's battery can be used as a local generator. PHEVs have a capacity of 4-15 kWh, which can be used as the owner's battery backup system to power her home or sell to her employer if the price is adequate."*

Other market challenges are related to the need for improved charging infrastructure at PHEV owner homes, and in public locations. To upgrade from an existing Level 1 plug, which a PHEV owner may already have in a garage, to a much faster charging Level 2 plug charging, would cost about $1,000 on top of the PHEV cost premium. Furthermore, in the absence of federal or state incentives, investments in charging infrastructure in public locations will likely follow behind the penetration rate of PHEVs which, in turn, may dampen PHEV demand and acceptance by consumers.

Finally, an often neglected barrier to PHEV or EV penetration is the public acceptance of plug-in charging as a routine: early experiences with converted PHEVs indicate that owners often find the plug-in process inconvenient or cumbersome, and neglect to plug in their vehicles. The importance of public education about PHEV technology and its benefits, as well as technologies aimed at simplifying the charging process or giving the owners increased control (e.g. through mobile devices or the internet), should not be underestimated.

Conclusions

PHEVs and pure EVs can offer a number of substantial benefits, including:

- Significant displacement of oil as the primary energy source in the transportation sector, and thereby a significant reduction in the nation's dependence on oil.
- Reduced environmental footprint, especially when combined with renewable sources in the electricity generation mix.
- A range of technological and economic opportunities created by interactions between electrified transportation and the electric power grid, including managed charging scenarios that allow electric vehicle integration in significant numbers without the need for increased generation capacity.

These benefits will be realized over the long-term, because it will take many years for a sufficient number of new plug-in vehicles to penetrate the market. The two predominant barriers to PHEV and EV market penetration include cost premiums related to batteries and charging infrastructure, as well public acceptance of the paradigm shift to plugging-in as opposed to fueling-up.

The main catalyst of the PHEV market will continue to be its environmental advantages. PHEVs and EVs emit less air pollutants and greenhouse gases than conventional cars due to their better efficiency and mileage, and the possibilities for superior emission controls at electrical power plants. In addition, any rising fuel costs would clearly contribute to accelerated adoption of PHEVs and EVs.

Policy interventions at the federal level may include fuel-efficiency mandates to vehicle manufacturers, subsidies to the purchasers of PHEVs, as well as taxes or restrictions on gasoline. On the policy front, the Obama Administration made a pledge to put 1 million PHEVs on the road by 2015. This is part of the "New Energy for America" plan to invest $150 billion over the next ten years to reduce dependence on foreign oil, and to accelerate the private sector's investment into sustainable, clean energy sources. By setting policy, the federal government can accelerate the large-scale volume sales of PHEVs that will be needed to reduce petroleum consumption.

> *"Finally, an often neglected barrier to PHEV or EV penetration is the public acceptance of plug-in charging as a routine: early experiences with converted PHEVs indicate that owners often find the plug-in process inconvenient or cumbersome, and neglect to plug in their vehicles."*

RECOMMENDATIONS

Overall, the automotive market is ripe for large-scale deployment of PHEVs and EVs but certain barriers must be overcome. The following recommendations include suggestions to overcome these barriers.

- Legislating increasingly stringent CAFE standards to raise vehicle mileage standards to 45 mpg or higher, which could be accomplished by hybridizing all vehicles.
- Offset the PHEV and EV cost premium to the consumer to encourage increased purchases and put downward pressure on price through volumetric sales. These offsets can be in the form of subsidies to the purchaser, possibly greater than the current federal tax credit of up to $7,500.

- Develop state incentives or subsidies to build the charging infrastructure needed for PHEVs.
- Adjusting state laws and local policies to allow PHEV access to HOV lanes or preferred parking spaces.
- State and local governments, as well as the utilities, could help the PHEV and EV market by including PHEVs and EVs in their fleets. Specifically, this would increase the volume of early sales, offer market certainty to manufacturers and promote technology demonstrations. Even more importantly, this could facilitate testing of various charging scenarios as well as charging infrastructure needs. Furthermore, this would increase public awareness of the technology and its impacts.
- Electric utilities, in collaboration with automotive manufacturers and research institutions, should explore effectiveness and public acceptance of various PHEV managed charging scenarios.
- Utilize smart grid technologies, as well as the existing internet and mobile device resources, to enable users greater, not less, control of the charging process. Empowering and rewarding the consumer is much more likely to produce mutually beneficial effects and to help accelerate adoption of PHEVs and EVs, especially in the early stages.
- Colorado, utilities, and automotive manufacturers should support public education and awareness programs related to: PHEV and EV technologies, benefits and impacts of transportation electrifications, and public acceptance of the emerging paradigm shift in the vehicles' everyday use.
- Utilities, in collaboration with automotive manufacturers and research institutions, should continue to explore technical and economic opportunities for vehicle-to-home and vehicle-to-grid technologies.
- Effective standards related to plug-in vehicle and grid integration technologies should be further established with participation by all interested parties: utilities, the automotive industry, research institutions, and governments.
- Colorado should prepare to match federal dollars for electric power R&D, including R&D related to battery technologies, charging infrastructure, and relevant smart grid technologies.
- The state of Colorado has traditionally not been a major hub for automotive-related industries or services. The paradigm shift to vehicle electrification opens ample opportunity for new players, including small and start-up businesses, to have a more significant presence in the new energy economy at the intersections of emerging transportation, smart grid, renewable energy, and information technologies. Colorado state policies and incentives should be aligned to support these goals[7].

GRID AND CYBER SECURITY

Jose Ramon Santos, Arun Gerra

ABSTRACT: *This chapter focuses on cyber security and the smart grid, specifically attacks on systems that can take place internally (within the utility company) or remotely (attacks by anyone, anywhere in the world). The chapter has three sections: (1) Introduction, (2) Background and Context, and (3) Key Issues and Recommendations.*

INTRODUCTION

The current power grid is not advanced enough, both technologically and resource-wise, to meet future energy demands and to respond to grid destabilizing events, such as accidents and attacks.[1] Deficiencies in the Colorado grid can be seen through the recent explosion and fire at the Xcel Energy power substation in Denver. The explosion resulted in millions of dollars in damages, and wide-spread power outages. The power outage affected residential consumers, as well as local hospitals, large industries, and the functioning of traffic lights. After five days, the substation was not completely repaired and local power was being supplied through a temporary transformer. In terms of grid destabilizing events, the explosion was minor; if a power plant experienced a similar accident the consequences could be catastrophic.

Some of the issues faced by the current power grid are portrayed below:

Figure 1 . Issues around Today's Power Grid

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[1] Wolf, Jeffrey. (2010, June 10). Xcel says temporary transformer running at substation. 9NEWS.COM, ***available at*** http://www.9news.com/rss/article.aspx?storyid=140795.

BACKGROUND AND CONTEXT

In an attempt to modernize the current grid and address the issues noted in Figure 1, the Energy Independence and Security Act of 2007 introduced a plan to reconfigure and enhance the current grid. The modernization of the grid is frequently referred to as the smart grid. Smart grid is basically a two-way communication system in which consumers will have control over their electric usage with the help of real-time price updates from utilities.[2] The smart grid integrates information technology (IT) and telecommunications systems into the current power grid to track energy utilization, monitor control systems, introduce renewable energy sources, enable energy storage, meet peak demand, detect faults, and prevent outages.

Currently, the power grid is most susceptible to attacks on physical locations. However, once IT and telecommunication technologies are introduced into the system, the grid will become highly susceptible to cyber and network attacks too.

> *"Currently, the power grid is most susceptible to attacks on physical locations. However, once IT and telecommunication technologies are introduced into the system, the grid will become highly susceptible to cyber and network attacks."*

The smart grid will be able to monitor every node in the future power grid, as shown in Figure 2 below:

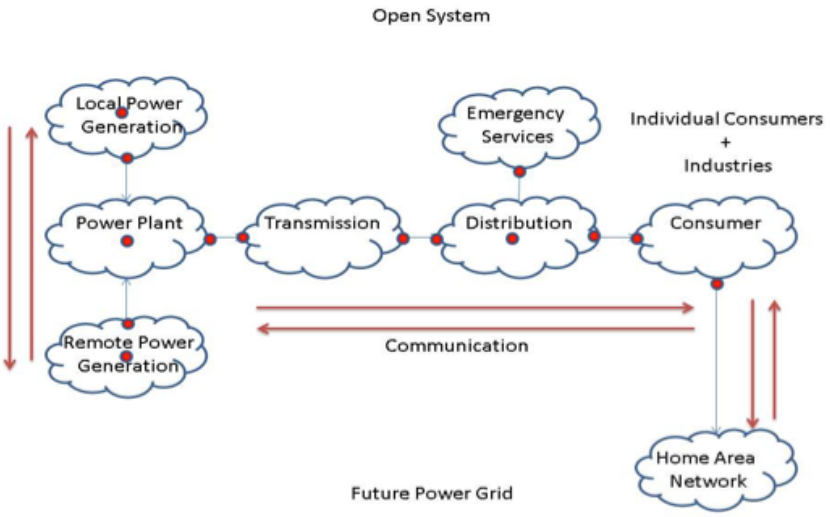

Figure 2. All Nodes Able to be Monitored

The current power grid is a closed system, and almost entirely isolated from outside cyber-penetration. As such, the main security concern for utilities is protecting against physical attacks. With the introduction of smart grid and communication protocols, however, utilities will now have to implement logical security in addition to physical security. Logical security consists of software safeguards and other computer securities, such as malware, spyware, network intrusion, viruses, software bugs, Denial of Service attacks, remote data theft, tampering with

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[2] Federal Smart Grid Task Force – Document – The Smart Grid: An Introduction, *available at* http://www.oe.energy.gov/DocumentsandMedia/DOE_SG_Book_Single_Pages.pdf.

smart meter firmware, and more.

In general, cyber-security threats to the grid take two forms: internal and external.

Internally, an employee working in the control operations of the power plant has access to monitoring software and can control systems remotely. Without adequate security and monitoring an employee could purposefully or accidentally cause harm or disruption of power to the grid. In addition to disruptions caused by control system manipulations, employees could compromise the safety and privacy of consumers through access to personal information. Utilities have the personal electric usage information of every consumer, industry, government department, etc., as well as the personal information of consumers. This information should be protected from internal employees, since it is a matter of privacy and confidentiality.

While the major U.S. power outages to date were caused by natural disasters or peak demand failures, cyber-attacks on the smart grid could also cause wide-spread power outages.

It is important to note that cyber-attacks do not only refer to computer attacks performed by hackers. Cyber-attacks can also include issues and attacks triggered by the improper fixing of software problems, bugs in system software, and human error with network operations.

Major Power Outages and their Cause[3]

A. New York, 1977	**Cause:** Lightning strike
B. Western North America, 1996	**Cause:** Summer over-demand of power
C. California, 2000/2001	**Cause:** Market manipulation and series of events
D. Northeast U.S., 2003	**Cause:** High electric demand

Cyber-Security Attacks on the U.S. Power System[4]

A. According to some national security officials, cyber-spies penetrated the U.S. electrical grid in 2009 and installed software programs that could be used to disrupt the system.[5]

> "Over the past several years, we have seen cyber-attacks against critical infrastructures abroad, and many of our own infrastructures are as vulnerable as their foreign counterparts," Director of National Intelligence, Dennis Blair, told lawmakers.

B. In Figure 3 (still shot from video released by the U.S. Department of Homeland Security), smoke pours from an expensive electrical turbine during a March 4, 2007 demonstration by the Idaho National Laboratory, which was simulating a hacker attack against the U.S. electrical grid.[6]

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[3] List of Power Outages. Retrieved June 17, 2010, from Wikipedia, ***available at*** http://en.wikipedia.org/wiki/List_of_power_outages.

[4] Most of the events are borrowed from news articles, and statements from secret intelligence officers, since there are no official records describing these attacks.

[5] Gorman, Siobahn (2009, April 8). Electricity Grid in U.S. Penetrated By Spies. The Wall Street Journal, ***available at*** http://online.wsj.com/article/SB123914805204099085.html.

[6] Associated Press (2007, September 27). U.S. video shows hacker hit on power grid, ***available at*** http://www.usatoday.com/tech/news/computersecurity/2007-09-27-hacker-video_N.htm.

Figure 3. Turbine a Victim of Grid Hacking (Simulated)

C. 2003 Northeast United States Blackout: one cause was an alarm system failure due to a computer bug in Energy Management System (EMS) software.[7]

D. In 2009, the security firm, IOActive, Inc., found flaws in a smart meter device that allowed a computer worm to be injected into the device and infect the local power network.[8]

E. KillerBee, an open-source hacking tool, can be used to explore and exploit the security of ZigBee, and other wireless personal area networks. KillerBee can be used to eavesdrop on "secure" networks, replay traffic, attack systems, and much more.[9]

F. 1999 Moonlight Maze attacks: there were a number of attacks on U.S. computer systems for a period of two years. The attacks were traced back to a mainframe computer in Moscow, but it was unclear where they originated from or who was responsible for the attacks.[10]

KEY ISSUES AND RECOMMENDATIONS

A. Asset Identification

Identification of all utility assets is desirable. Assets include everything from energy resources, power generators, transmission towers, distribution channels, transformers, voltage regulators, circuit breakers, and smart meters. Assets also include the SCADA running systems, firewalls and routers used for network protection, data storage, web servers, and file servers. Utilities need to create a detailed network diagram identifying all the above assets and their locations. A Graphical User Interface (GUI) would be extremely useful in this task. GUIs

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[7] Biot Report# 391 (2006, August 24). North American 2003 Electric Power Outage: Prime Example of Hidden Failure in a Critical Networked Infrastructure, ***available at*** http://www.semp.us/publications/biot_reader.php?BiotID=391.

[8] Davis, Mike (2009). Smart grid Device Security - Adventures in a new medium [PowerPoint Slides], ***available at*** http://www.blackhat.com/presentations/bh-usa-09/MDAVIS/BHUSA09-Davis-AMI-SLIDES.pdf.

[9] Wright, Joshua (2010).KillerBee: Practical ZigBee Exploitation Framework [PowerPoint Slides], ***available at*** http://inguardians.com/pubs/toorcon11-wright.pdf.

[10] The Tecnolytics Institute. (2007, November) Department of Cyber Defence [Online Publication], ***available at*** http://www.technolytics.com/Dept_of_Cyber_Defense.pdf.

provide information about a particular asset, describing the location, employees involved in upgrades, contact information, personnel responsible for the system, recent repairs and upgrades, remote control capabilities, internet connections, connections to perimeter security firewalls involved with personnel responsible, level of risk, and more. This interface provides a holistic view of the identified system. Similarly, asset identification should be performed for all the systems. While it is time-intensive for utilities to identify all of their assets, it is imperative to know what is owned and operating before additional developments are made.

Recommendations

- Identify all assets
- Responsibility for assets: a layered approach should be adopted which gives an overview of personnel responsibilities for each particular asset, and escalations or delegations (if any).
- Information and asset classification: a detailed network diagram with classification and physical and logical access controls should be defined. Systems should be hardened to extreme levels, and checks on the integrity of the systems should be continuous.
- Categorize assets with respect to risks involved.
- Follow a cycle for assets involved, and highlight issues at each level where the power grid can be compromised. See Figure 4:

Figure 4. Asset Cycle

B. Categorize Assets — Impact On Grid

The assets defined above should be categorized by risk of attack. The categorization should correlate to the level of impact on the grid: low, medium, and high. In addition, the potential effects of asset attacks or failures on the grid should be documented in detail. In the case of an attack: Can the asset be repaired immediately? Do parts need to be imported from outside the country? How long will the downtime be? What effect will the downtime have on the region? Is there any cascading effect?

Recommendations

- Categorize assets with respect to risks involved
- Structure out detailed impacts on the grid for each asset, as shown below:

ASSET	LEVEL OF RISK	IMPACT ON GRID	PHYSICAL / LOGICAL	REPAIR OR NEED TO IMPORT	PERSONNEL RESPONSIBLE FOR REPAIR	PERSONNEL RESPONSIBLE FOR IMPORT	CASCADING EFFECT?
Transformer	High	High	Physical	Repair	Mr. X	-	Yes

Figure 5. Risk Categorization

C. RISK ASSESSMENT

Below, in Figure 6, the vulnerable areas of the future smart grid are highlighted. The power grid is divided into eight main regions: Power Plant, Remote Power Generation, Transmission, Distribution, Consumer, Home Area Network, Emergency Services, and Internet.

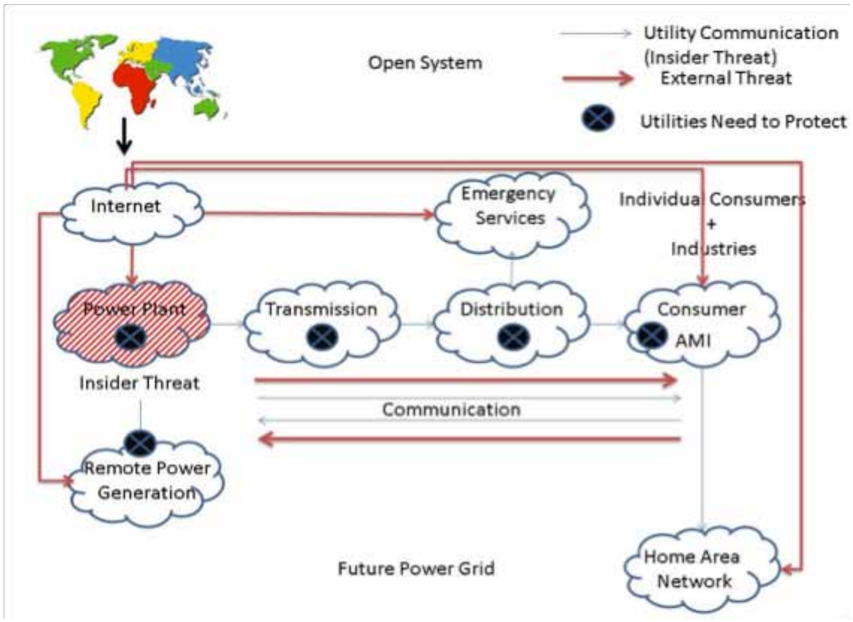

Figure 6. . Vulnerabilities and Each Utility's Protection Responsibilities

After identifying the risks associated with identified assets, the next step is to provide complete risk assessment. There are three main steps in this process:

1) Risk Identification
    a. Physical
    b. Logical
2) Risk Analysis

3) Risk Management[11]
  a. Avoidance
  b. Transference
  c. Mitigation
  d. Acceptance

1) **Risk Identification:** assets risks should be categorized into physical or logical risks.

   a. **Physical Risks:** physical attacks, including natural disasters and sabotage. In the past, most terrorist attacks have been physical, not logical.

   b. **Logical:** types of cyber and computer system attacks. Logical risks should be identified at every point of access to the system, whether external or internal. Logical risk identification can prevent a hacker who gains access to the internal network of the power utility from causing disastrous effects to the grid. No harm can be done from outside apart from Distributed Denial of Service (DDoS) attacks.

> *"According to some national security officials, cyber-spies penetrated the U.S. electrical grid in 2009 and installed software programs that could be used to disrupt the system."*

2) **Risk Analysis:** risk analysis involves determining the probability that a particular risk will occur. Every possible risk should be evaluated with respect to the systems involved. The data extracted from risk analysis should be used to identify potential issues that could have any negative impact on the power grid.

3) **Risk Management**

   a. **Avoidance:** the point of risk management is to proceed with caution when determining if any upgrades or new systems are required. Assuming that new upgrades are required, they can increase risk by creating more access points in the system, points which could be breached. In depth planning, extra resources, and extra time taken to determine exactly what is needed is essential to reducing the scope of high-risk activities and avoiding these activities altogether.

   b. **Transference:** risk transference attempts to shift the consequences of a risk to a third party along with the responsibility of responding to the risk. However, risk transference does not eliminate the risk completely. Utilities can purchase insurance to cover the cost of the risk. In the case of smart meters, proper agreements should be in place with the third-party vendors that determine who will be responsible in the event of smart meter tampering and how various situations involving remote firmware upgrades of meters, remote monitoring, repairs, etc. will be resolved. Another third-party concern comes from data processing; the data gathered by utilities that pertains to power usage in consumer homes will be provided to a third party for processing. Occasionally, Managed Security Service Providers (MSSPs) are used to monitor utility network security. In these cases, detailed agreements should be in place with respect to the kinds of services that will be offered, vulnerability management, incident response, and additional risk response protocols.

   c. **Mitigation:** mitigation seeks to reduce the probability and consequences of an adverse risk to an

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[11] (2008) Risk Assessment Worksheet and Management Plan [Document], *available at* http://www.pmhut.com/wp-content/uploads/2008/01/risk_management.pdf.

acceptable threshold by taking actions ahead of time. If done correctly, mitigation can decrease the likelihood of a problem occurring.

d. **Acceptance:** the final technique for dealing with risk is to respond to the risk item with a contingency plan, should a problem occur. For example, if a task is at risk of being delayed, in the case of transformer repair, then the plan should be to add additional resources to the task. Contingency plans should include any work that must be done ahead of time to enable a successful contingency plan response.

Three factors are critical when dealing with the power industry: confidentiality, service availability, and security.

1) **Confidentiality:** Consumers should have confidence in the ability of utilities to keep electric data usage obtained through smart grid confidential and private.

2) **Service Availability:** utilities should be able to provide sufficient and immediate backup power in case of a power outage. Power outages affect consumers, industries, emergency services, and local hospitals—all of which suffer severe economic and functionality set-backs when they experience a loss of power. Utilities should be prepared to provide back-up power when distributed power and automation are involved.

3) **Security:** energy storage can also serve as a reserve source of power when outages occur, particularly for emergency services. Security should be put in place to protect backup energy storage power when power outages occur.

Recommendations

- Risk management should be employed using a top-down, risk-based approach.
- Third party service delivery: utilities need to have proper documentation in place that describes the services that will and will not be provided by third-party companies. Third-party companies include smart meter vendors, firmware, IT systems providers, software providers, etc.
- There should be a formal mechanism in place to monitor and review third party services.
- Managing changes to third party services: if there are any changes to the service agreement, utilities need to determine how these changes might affect the business, whether the new issues will be incorporated, and whether the utility can deal with them. If third-party vendors need remote access to upgrade or monitor their products, the utility must determine what security issues need to be addressed.
- Introduction of distributed power storage: the PUC and the Governor's Energy Office should make sure that basic services are available 24/7 in the event of an outage (i.e. police operations, local hospitals). Outages can be dealt with efficiently by using distributed storage maintained by utilities. *High priority should be given to these services.*

D. Security Investment

Security, in terms of smart grid, is extremely important. Utilities should never use cheap solutions to simply meet standards and compliances. Utilities will invite trouble and sabotage if they do not close the loopholes created by the integration of IT and telecommunication in the grid system. Fortunately, with proper security solutions in place, and with the help of security policies and procedures, the risks involved can be minimized.

NIST is developing standards for smart grid cyber security, but many utilities have begun smart grid deployment without comprehensive security standards. Colorado should take care to ensure that utilities meet the required security standards. Apart from NIST Standards, individual governments can have their own security practices for utilities. Utilities should protect consumer data, power breach explicitly with some priorities, but invest resources so they cannot be blamed for security breaches. Any security attack on a utility will have a long cascading effec — from utility to industry, industry to manufacturing, manufacturing to consumer markets. More often than not, it is more devastating to see the affects of power outages on financial institutions because of the lasting effects on the national and even global economy.

Recommendations

- The State of Colorado should consider a requirement that utilities explicitly provide security solutions to their consumers. The levels of security to protect a continuous supply of power might differ, depending on whether the customer is an individual or an industry. For example, in the event of a power outage, emergency services should be top priority. Accordingly, utilities should prioritize service reliability dependent upon customer category:

  1) Emergency Services
     a. 911 Calls
     b. Local hospitals
     c. Consumers with lifesaving equipment at home
     d. Police operations
  2) Financial Institutions
  3) Industries
  4) Consumers
  5) Medium-scale industry
  6) Small-scale industry

E. Protect & Monitor

Most of the utilities today consist of infrastructure which is more than 40 years old. 40 years ago, security was not an issue and networks were implemented for intranet communication without keeping security issues in mind.

Today, security should be implemented to protect the power grid from physical and logical security attacks. Log Management plays a significant role in every industry; all operating systems, control systems, software applications, perimeter firewall, SCADA systems, etc. send feeds to a log management software or application. These are also important for monitoring from an incident response point of view. Internal networks should also be protected and proper system hardening steps should be practiced.

The key to accurate network protection is isolation. Utilities should ensure that the networks are isolated and not inter-dependent on one another, as this can prevent a cascading communication breach. The network used by internal employees for email and web browsing should be isolated with respect to the control system operation center, as well as subnets used for two-way communication. Further, utilities should continuously monitor all the network connections. While wireless is the easiest solution for communicating from smart meter to operations center, it is more vulnerable than physical mediums.

One thing that might be difficult for every utility is to not disclose the physical location of power plants.[12]

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[12] Clemente, Jude (2009, June 18). The Security Vulnerabilities of Smart Grid. Journal of Energy Security, ***available at*** http://www.ensec.org/index.php?option=com_content&view=article&id=198:the-security-vulnerabilities-of-smart-grid&catid=96:content&Itemid=345.

Many online web applications, like Google Earth, provide information regarding plant locations in the U.S. and directions to them.[13] This information can be used by terrorists, or anyone, to plan an attack on a power plant. For example, the recent attack in Mumbai by terrorists was planned using Google Maps. The state of Colorado, and other government organizations, should take care regarding disclosure of critical locations that can be targeted by terrorist attacks.

Another important step that every utility needs to take (and government organizations need to make sure that they do) is to not provide open source information to the public regarding the construction of new power plants and new developments for security practices via the web. Reconnaissance is a type of activity that provides individuals with access to online resources, allowing them to track a power plant's development. Recruitment practices that hire individuals for control and security operation departments should include proper background checks and secret clearance. Steps should also be taken to guarantee that employees are suitably trained and educated before giving them access to critical control systems. Access control, roles, and responsibilities should be documented as well.

Recommendations

- *Isolation of networks* and *no inter-dependency* between neighboring smart meters, or any critical infrastructure, is the first step in creating secure networks. The less the inter-dependency, the more secure the network, which will minimize cascading effects on the power grid. The ability to isolate networks in a micro-grid configuration may allow for maintaining the advantages gained from an interconnected system.
- Colorado should consider *restricting online street maps* from disclosing the information and locations of Critical Infrastructure Systems and major power plants, as these installations and systems are relatively easy targets for terrorist attacks.
- Utilities should consider *disclosing the minimum amount of information necessary* regarding their movements, security developments, and infrastructure updates on the web, because such information might attract unnecessary attention from people whose motive is to disrupt the power grid. For example, if Utility X announces partnership with Company Y for purchase of routers, switches, and firewalls, then everyone privy to that information could potentially learn the ways in which the system can be exploited (as, for example, the system components are manufactured by Company Y, and this company uses type Z proprietary software).
- Human resources security should be rigorously addressed: i.e., strict hiring procedures, roles and responsibilities, security awareness, education and training.
- There should be a formal, recurring and iterative process for reporting information on security events and weaknesses.
- There should be continuous monitoring of the activities of internal employees, as an attack is more severe from the inside.

F. Review and Update

All of the things discussed above cannot to be implemented on a one-time basis, but require continuous attention. Utilities should follow these steps, and have monthly update systems to publish reports within the internal organization involved.

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[13] Bedi, Rahul (2008, Dec 8). Mumbai attacks: Indian suit against Google Earth over image use by terrorists. Telegraph.co.uk News, ***available at*** http://www.telegraph.co.uk/news/worldnews/asia/india/3691723/Mumbai-attacks-Indian-suit-against-Google-Earth-over-image-use-by-terrorists.html.

Recommendations

- Maintenance of equipment: quarterly checks should be performed on all critical systems to maintain the power grid.
- Change of control management.

G. Issues Related To The Consumer

1) **Real-Time Data:** with the help of regular price updates from utilities, the smart grid will help consumers use energy more efficiently. Utilities will receive electric usage data from every consumer, be it from individual households or industries. This data will help utilities to plan energy generation and meet peak power demands in more efficient ways. But this real-time data gathering comes with the risks of mismanagement of private consumer information and cyber-attacks aimed at obtaining consumer data.

2) **HAN (Home Area Network):** in the future, consumers will have their own internal network connecting various appliances and smart meters. This network is called a HAN, and the configuration of this network will be provided by either the utility or a third-party company. Appliances like thermostats, washing machines, air conditioners, nodes for electric vehicles, and other heavy appliances will contain a sensor which will communicate with smart meters using Zigbee wireless protocol. If a third-party HAN provider is involved, then that particular company needs to have an agreement that determines how someone will respond to any abnormality or malfunction in the HAN network. If there is any abnormality in the HAN network, then the data sent to a power utility about electric usage will be incorrect, and this will require the power utility to investigate the problem. A third-party HAN provider should be able to investigate the situation, and have proper agreements with the utilities with respect to addressing abnormalities.

3) **Hacking into HANs:** in the case of consumers tampering with the network, consumers will be responsible to utilities and HAN providers. However, if the breach is from a hack by neighbors or outsiders, there needs to be a way for the consumer to prove that it was not his or her fault. This is an important issue that needs to be addressed by utilities, and should be part of consumer protection regulation.

4) **Hacking into Web Portals or Displays:** the real-time pricing data will be displayed on some web portals provided by either third parties or utilities. Again, the same issue arises: in the case of network intrusion into the consumer's home and attempts to hack into the web portal, there needs to be a way to identify and track the hacker's activities.

5) **Need for Legislators and Regulators:** utilities must have proper documentation in place that addresses issues related to tampering with smart meters. Smart grid and HANs are extremely complicated. Thus, legislatures and regulators should come up with requirements that determine who will be responsible for every part of the interface between smart grid and HANs in order to protect consumers from any attempts to hack into the system.

Recommendations

- Consumers need to be *protected from malfunctions in HANs*. These malfunctions can be caused by interference from anyone. Colorado must consider who will bear the responsibility for malfunction issues, whether it is the consumer or HAN provider, and consider the steps to determine who tried to gain unauthorized access and tamper with the HAN.
- Similarly, the issue of *unauthorized access to web portals* must also be addressed.
- Utilities should incorporate distributed energy to make sure there is an availability of power in case of outages.

IMPACTS OF SMART GRID ON CO_2 EMISSIONS

Rebecca Johnson

ABSTRACT: *Smart grid-enabled demand response has the potential to increase marginal CO_2 emissions significantly. However, bundling demand response with energy efficiency and renewable electricity requirements results in overall reductions in CO_2 emissions. Key to achieving the full CO_2 benefits of smart grid is intelligent integration of smart grid, energy efficiency, and renewable energy policies which include all providers of electricity in Colorado. It has two parts: (1) Background and Context and (2) Key Issues and Recommendations.*

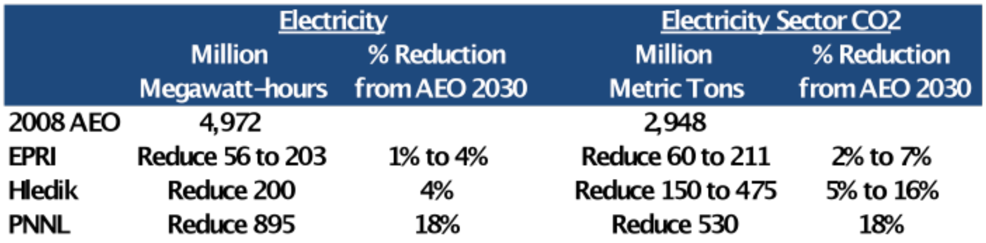
BACKGROUND AND CONTEXT

Smart grid is a subject of great public interest as a means to enable a more efficient and renewably-powered electric grid infrastructure. Considerable public and private investment in smart grid is driven, in part, by the belief that it will provide significant environmental benefits, including CO_2 emissions reductions.

Smart grid is hypothesized to influence CO_2 emissions from the electric sector by facilitating energy efficiency, demand response, and renewable energy integration via smart grid-enabled tools which include remote sensing and control, advanced communications, increased situational awareness, increased operational control, time-sensitive pricing, and programmable and signal-responsive equipment. Assuming appropriate policy support, smart grid research suggests that significant reductions in CO_2 emissions are possible.

Review of Three Studies Concerning the Impact of Smart Grid on Electric Utility Sector Co_2 Emissions

Three notable studies of the national impact of smart grid on electric utility sector CO_2 emissions have been published to date: "The Green Grid," published by the Electric Power Research Institute (EPRI) in May of 2008[2]; "How Green is the Smart Grid?," written by Ryan Hledik and published in the *Electricity Journal* in April of 2009[7]; and "The Smart Grid: An Estimation of the Energy and CO_2 Benefits," published by the Pacific Northwest National Lab (PNNL) in January of 2010.[9] The estimated reductions in energy and CO_2 vary dramatically across the studies, as seen in Table 1.



	Electricity		Electricity Sector CO2	
	Million Megawatt-hours	% Reduction from AEO 2030	Million Metric Tons	% Reduction from AEO 2030
2008 AEO	4,972		2,948	
EPRI	Reduce 56 to 203	1% to 4%	Reduce 60 to 211	2% to 7%
Hledik	Reduce 200	4%	Reduce 150 to 475	5% to 16%
PNNL	Reduce 895	18%	Reduce 530	18%

Table 1. Estimated Reductions in Energy and CO_2 [2,3,7,9]

"The Green Grid" [2]

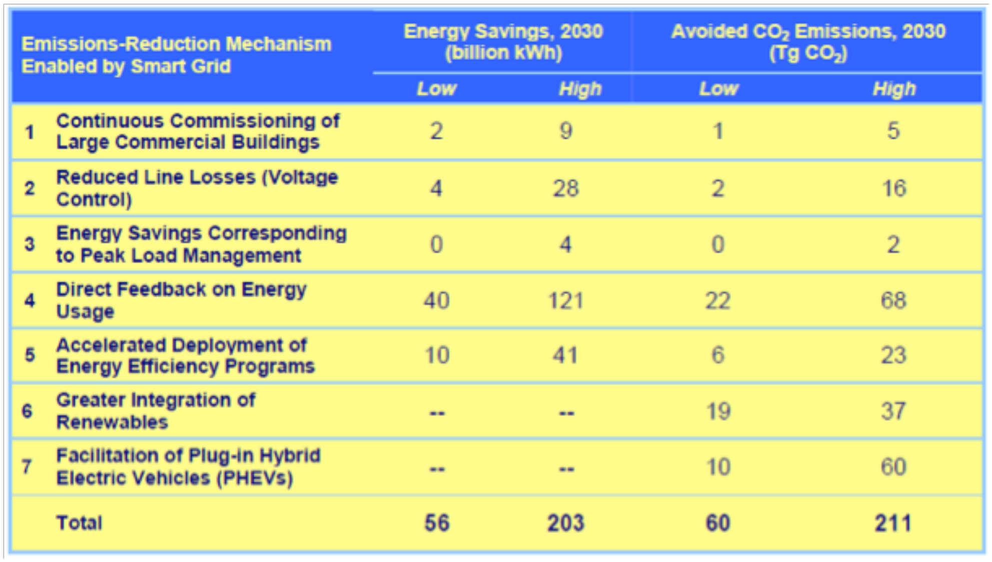
The EPRI analysis estimated that smart grid could lead to CO_2 reductions of 2% to 7% by 2030. The study characterized smart grid as an integrated set of four building blocks:

- Communications infrastructure,
- Innovative rates and regulation,
- Smart end-use devices, and
- Innovative power markets.

The study hypothesized that smart grid could facilitate energy, and hence CO_2, reductions via seven mechanisms including: continuous commissions of large commercial building, reduced line losses, energy saving from improved peak load management, direct feedback on energy usage, accelerated deployment of energy efficiency programs, greater integration of renewable energy sources, and facilitation of Plug-in Hybrid Electric Vehicles (PHEVs).

The EPRI analysis calculated CO_2 reduction estimates based on net energy savings. For every 1 billion kWh of estimated energy savings, the equivalent of 0.64 Tg of CO_2 emissions were assumed to be avoided. This carbon intensity is based on a "contemporary U.S. generation mix."

> *"In a January 2010 analysis, the Pacific Northwestern National Lab (PNNL) estimated potential energy and CO_2 reductions attributable to smart grid to be approximately 18% by 2030."*



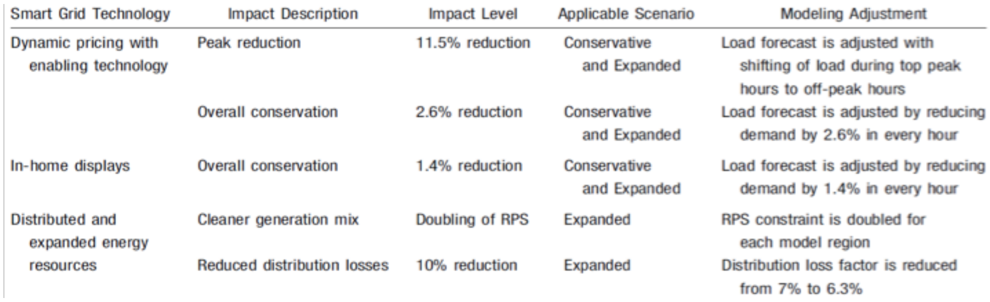
	Emissions-Reduction Mechanism Enabled by Smart Grid	Energy Savings, 2030 (billion kWh)		Avoided CO_2 Emissions, 2030 (Tg CO_2)	
		Low	High	Low	High
1	Continuous Commissioning of Large Commercial Buildings	2	9	1	5
2	Reduced Line Losses (Voltage Control)	4	28	2	16
3	Energy Savings Corresponding to Peak Load Management	0	4	0	2
4	Direct Feedback on Energy Usage	40	121	22	68
5	Accelerated Deployment of Energy Efficiency Programs	10	41	6	23
6	Greater Integration of Renewables	--	--	19	37
7	Facilitation of Plug-in Hybrid Electric Vehicles (PHEVs)	--	--	10	60
	Total	**56**	**203**	**60**	**211**

Table 2. EPRI Emissions Reductions Enabled by Smart Grid[2]

"How Green is the Smart Grid"[7]

The next study in the chronology, Ryan Hledik's Brattle Group analysis, differed in that it addressed differences in regional electricity system characteristics and also because it employed linear modelling to estimate CO_2 reductions.

Hledik estimated that a smart grid could lead to a reduction in CO_2 emissions, on the national level, from 5% to 16% per year by 2030. His analysis contemplated two scenarios: a conservative scenario based on technologies that are commercially available including advanced metering, dynamic pricing, automating technologies, and information displays; and an expanded scenario that coupled the impacts of the conservative scenario technologies with the impacts of a smart distribution system and an increase in distributed energy resources. A summary of the estimated technology impact levels and modeling adjustments is shown in Table 3.



Smart Grid Technology	Impact Description	Impact Level	Applicable Scenario	Modeling Adjustment
Dynamic pricing with enabling technology	Peak reduction	11.5% reduction	Conservative and Expanded	Load forecast is adjusted with shifting of load during top peak hours to off-peak hours
	Overall conservation	2.6% reduction	Conservative and Expanded	Load forecast is adjusted by reducing demand by 2.6% in every hour
In-home displays	Overall conservation	1.4% reduction	Conservative and Expanded	Load forecast is adjusted by reducing demand by 1.4% in every hour
Distributed and expanded energy resources	Cleaner generation mix	Doubling of RPS	Expanded	RPS constraint is doubled for each model region
	Reduced distribution losses	10% reduction	Expanded	Distribution loss factor is reduced from 7% to 6.3%

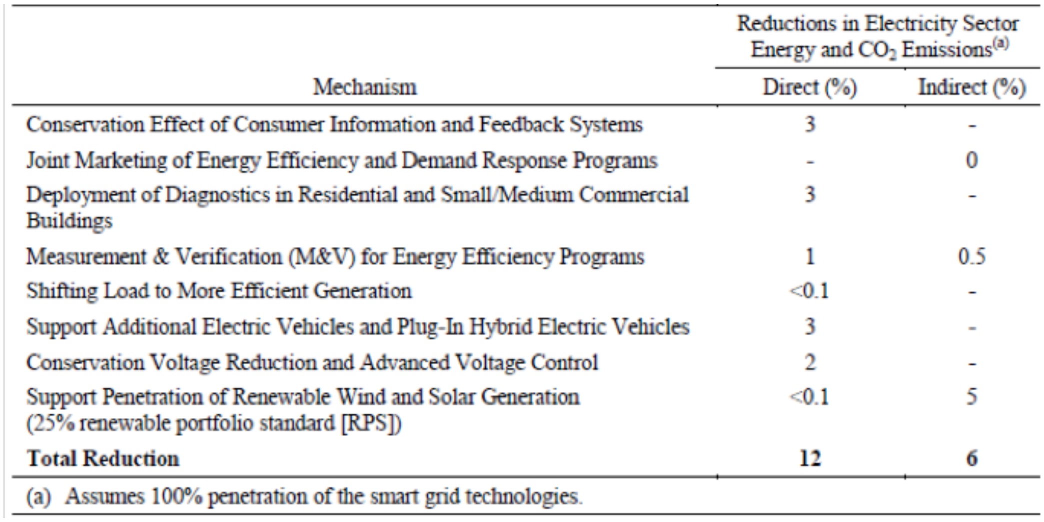
Table 3. Hledik Summary of RECAP Impact Levels and Modeling Adjustments[7]

The Smart Grid: An Estimation of the Energy and CO_2 Benefits”[9]

In a January 2010 analysis, the Pacific Northwestern National Lab (PNNL) estimated potential energy and CO_2 reductions attributable to smart grid to be approximately 18% by 2030.

The PNNL study identified seven smart grid technologies that could contribute to potential reductions in electricity and CO_2 emissions. These include: conservation effect of consumer information and feedback systems, joint marketing of energy efficiency and demand response programs, deployment of diagnostics in residential and commercial buildings, measurement and verification for energy efficiency programs, shifting load to more efficient generation, supporting additional electric vehicles and PHEVs, conservation voltage reduction and advanced voltage control, and supporting penetration of renewable wind and solar generation.

With a methodology similar to EPRI’s, the PNNL study estimates CO_2 reductions as being directly correlated to energy reductions for each of the identified mechanisms. The PNNL study uses an average CO_2 intensity of 0.59 metric tons per megawatt-hour.



	Reductions in Electricity Sector Energy and CO_2 Emissions[(a)]	
Mechanism	Direct (%)	Indirect (%)
Conservation Effect of Consumer Information and Feedback Systems	3	-
Joint Marketing of Energy Efficiency and Demand Response Programs	-	0
Deployment of Diagnostics in Residential and Small/Medium Commercial Buildings	3	-
Measurement & Verification (M&V) for Energy Efficiency Programs	1	0.5
Shifting Load to More Efficient Generation	<0.1	-
Support Additional Electric Vehicles and Plug-In Hybrid Electric Vehicles	3	-
Conservation Voltage Reduction and Advanced Voltage Control	2	-
Support Penetration of Renewable Wind and Solar Generation (25% renewable portfolio standard [RPS])	<0.1	5
Total Reduction	**12**	**6**

(a) Assumes 100% penetration of the smart grid technologies.

Table 4. PNNL Summary of Potential Reductions in Electricity and CO_2 Emissions Attributable to Smart Grid Technologies[9]

While research suggests that smart grid has the potential to contribute to meaningful reductions in CO_2 emissions, smart grid technologies alone will be insufficient to achieve this objective. Smart policies are also necessary to support state-wide deployment of effective demand-side management, renewable energy integration, and smart grid.

KEY ISSUES AND RECOMMENDATIONS

There are three key issues which will affect the ability of smart grid to contribute to reductions in CO_2 emissions. Following is a summary of the issues and the recommended policy objectives.

Issue 1: *Demand response without sufficient energy efficiency and renewable integration may increase marginal* CO_2 *emissions.*

While demand response-enabled load shifting is beneficial in terms of reducing system operating costs, deferring the need for capacity expansion, and protecting system reliability, it is important to recognize that demand response that shifts load from peak to off-peak hours without reducing overall demand may increase CO_2 emissions. This occurs in systems where peak load is met with less CO_2-intensive natural gas generation and base load is met with more CO_2-intensive coal generation, as is the case in Colorado.[2]

In Colorado's fossil fuel-dominated electricity system, shifting load from peak to off-peak would increase marginal CO_2 significantly. The weighted average CO_2 intensity of natural gas generation is 0.53 metric tons per megawatt-hour and the weighted average CO_2 intensity of coal generation is 1.05 metric tons per megawatt-hour.10 On average, shifting a unit of generation from natural gas to coal increases the marginal CO_2 intensity by 98%.

> *"In Colorado's fossil fuel-dominated electricity system, shifting load from peak to off-peak increases marginal* CO_2 *significantly."*

Recommendation 1: *Emphasize the importance of energy efficiency as a partner to demand response and promote expansion of renewable integration.*

To avoid demand response-induced increases in CO_2 emissions, it is important to emphasize effective energy efficiency programs and to promote expansion of renewable energy integration. Renewable energy standards, distributed generation requirements, and distributed energy interconnection standards are all important partners to smart grid policy. It is recommended that Colorado's excellent renewable electricity policies be reviewed for alignment and consistency with smart grid policy, and be adjusted as necessary to ensure optimal coordination. Because of the risk of increasing marginal CO_2 emissions via smart grid-enabled demand response, it is important that smart grid policies apply to all electricity generators and retailers.

Issue 2: *The traditional utility business model is a disincentive to energy efficiency.*

The traditional utility business model is a disincentive to energy efficiency for two reasons: 1) revenue is linked to energy (kWh) sold, and 2) traditional demand-side management programs are based on utility expenditures as opposed to program performance.

Recommendation 2: *Deploy demand side management policies which reward both electric utilities and consumers for the performance of energy efficiency programs.*

A key benefit of smart grid is the ability to measure and verify energy efficiency savings. This opens the door to an alternate business model, shared savings, which has previously been limited in potential because of measurement and verification challenges.

With a shared savings program, the regulator and the utility negotiate an efficiency goal and then agree to a percentage of the savings that the utility can earn. Shared savings models are currently in use in California, Arizona, and Ohio. In the California program, if the utilities reduce demand by 85% to 99% of an agreed upon energy savings goal during a three year program cycle, they receive 9 percent of the verified net savings as a bonus. If they achieve 100% or more of the goal, they receive 12% of the savings as a bonus. If they fail to meet the goal, they are penalized and/or have to pay back the cost of the efficiency program to consumers. Shared savings programs are based on verified savings, not expenditures, which encourages the utilities to make cost-effective efficiency investments.[8]

Both types of efficiencies – power efficiency and energy efficiency – must be improved.

1) *Power efficiency* can be improved by about 15% with the use of appropriately sized motors. For example, using appropriately designed motors in consumer goods, like refrigerators, air conditioners, washing machines, and dryers, increases their power efficiency. Power efficiency can also be improved through the use high-efficiency lighting, such as LEDs or CFLs.

2) *Energy efficiency* can be improved by placing renewable sources close to the customers within the distribution system coupled with appropriate reactive power minimization devices to reduce the 9.5% transmission line losses.

Issue 3: Changes in consumer behavior are critical yet highly uncertain.

If consumers modify their behavior in response to smart grid, research suggests that meaningful reductions in energy consumption, and coincident CO_2 emissions, are possible. In a synthesis study, Ahmad Faruqui, et al. estimate that consumers may reduce overall electricity consumption by an average of 7% in response to smart grid-enabled technologies and pricing programs.[5]

However, a recent meta-analysis by Karen Ehrhardt-Martinez estimates that consumer adoption of smart grid-enabled technologies may range from 5% to 85%, depending upon whether the smart grid program is based on an 'opt-in' or an 'opt-out' structure.[1]

Confounding the estimation of potential smart grid-enabled energy and peak demand reductions is a lack of scientific rigor and consistency in the design of the underlying studies. Much work remains to be done in the analysis of consumer adoption of smart grid.[5]

Recommendation 3: *Seek to understand and share best practices concerning factors which will promote consumer adoption of smart grid.*

Consumer adoption of smart grid is dependent upon many factors, many of which are discussed in detail in other sections of this white paper. Critical factors include:

- Ownership and license of consumer data,
- Protection of consumer privacy,
- Time-variable electricity pricing,
- Effective energy efficiency incentives, and
- Consumer smart grid and energy efficiency education.

To conclude, smart grid-enabled demand response has the potential to increase marginal CO_2 emissions significantly. However, bundling demand response with energy efficiency and renewable electricity requirements results in overall reductions in CO_2 emissions. Key to achieving the full CO_2 benefits of smart grid is intelligent integration of smart grid, energy efficiency, and renewable energy policies which include all providers of electricity in Colorado.

RETAIL PRICING STRUCTURES

Stephen Lawrence

ABSTRACT: *This chapter focuses on retail pricing structures for the smart grid, and outlines innovative pricing structures that have the potential to reduce costs for both consumers and utilities. It consists of three sections: (1) Background and Context, (2) Key Issues, and (3) Recommendations.*

BACKGROUND AND CONTEXT

Background

Traditionally, retail customers have paid a single price for a unit of electrical energy (e.g., $0.10 per kWh). Smart grid technologies will allow rates structures to vary by the hour (e.g., cheap rates in the middle of the night; expensive rates during peak hours during the day), by the current cost of generating electricity, or by the current wholesale market price of electricity. Utilities currently must generate sufficient electrical power to meet customer demand at any moment, whatever it is. Aggregate demand for electricity varies significantly over any 24 hour period, with demand usually lowest during early morning hours and highest during late afternoon and early evening hours. In order to meet variations in demand, utilities employ different types of generating technologies to provide various levels of flexibility:

- **Base load generators** (coal and nuclear power plants, large hydroelectric dams) are used to provide a steady foundation of electrical power that does not vary much over time. These generators are not capable of varying their power output quickly or efficiently, but are economically the least expensive to operate ($10-25 per MWh).
- **Load-following generators** (combined cycle gas turbines, some hydroelectric dams) are used to meet components of demand that vary slowly over time (e.g., the normal variation between early morning and late afternoons). These generators can slowly vary their power output over time, but cannot do so quickly in a matter of minutes. Mid-load generators are often more expensive to operate than base load generators ($45-75 per MWh, but costs are highly dependent on fuel prices, such as natural gas).
- **Peaking generators** (gas peaking turbines; pumped hydro facilities) are designed to quickly respond to fluctuations in demand that varies over a matter of minutes. Most peaking units are gas turbines (essentially jet engines connected to generators) that can quickly be brought on line and modulated to meet rapidly changing demand loads. Peaking generators are the most flexible and responsive, but are much more costly to operate than base load or load following generators ($50-140 per MWh), and are more costly to acquire than other types of generators.
- **Spinning reserves** are on-line power units (e.g., load-following turbines, idle peaking turbines) that may be generating electricity, but are not operating at full capacity. This excess capacity can quickly be tapped to meet rapidly changing demand loads. By regulation, utilities are required to maintain adequate levels of spinning reserves, usually about 7% of forecast demand load. The cost of maintaining spinning reserves can be substantial ($50-145 per MW of reserve power).

Since generating power to meet peak demand levels is expensive, utilities are very interested in finding new ways to reduce peak demand level, and especially rapidly fluctuating peak loads, because these require the use of expensive peaking generators. There are two ways to reduce peak loads — demand shifting and peak shaving:[1]

- **Demand shifting** is the movement of customer demand loads from peak demand periods to low demand periods, such as shifting demand from late afternoons to early mornings. Mechanisms for shifting demand include time-of-day pricing and regulatory fiat. For example, many large industrial users of electricity have long paid higher rates for power during peak hours, and much lower or even discounted rates during off-peak hours. This encourages industrial and commercial users to organize their operations so that power is used during off-peak versus peak hours.
- **Peak shaving** is the reduction of demand during peak periods by eliminating some components of demand, such as curtailing operations of large power-intensive industrial operations. Mechanisms for peak shaving include pricing schedules and contractual agreements between electricity consumers and utilities. For example, with the permission of individual homeowners, many utilities are now installing cut-off devices on residential air conditioners that can then be turned off by the utility for a short time (e.g., 15 minutes) during periods of excessively high demand. In return, the homeowner enjoys a rebate or reduced electricity costs.

The benefits of peak shifting and peak shaving appear to be significant. For example, one study showed that a 1% reduction in peak demand could result in a 3.9% reduction in costs, worth billions of dollars at a system level. Nationally, a 10% reduction in peak demand would result in total savings of between $8 and 28 billion annually.[2] Another study found that a 5% drop in peak demand would allow 625 peaking power plants to be eliminated, yielding savings of $3 billion annually.[3] In Ontario, Canada, peak demand exceeded 25 GW during only 32 hours in 2006. Eliminating these infrequent peak demand spikes would allow Ontario to reduce its electrical generating capacity by almost 2 GW.[4]

Context

Currently, residential customers do not know how much electricity they consume until weeks after actual use when they receive their electricity bill. Since consumers do not have real-time information regarding power use, they cannot effectively take action or make decisions to reduce or shift demand. Further, residential consumers currently have little incentive to reduce or shift demand beyond good will, since there are no direct economic disincentives for using electricity during peak demand periods.

Promise of smart grid. Smart grid technologies hold the promise of making demand shifting and peak shaving much more widespread and effective. Smart grid technologies will enable better information for retail consumers, will facilitate the application of market forces to modify consumer behavior through pricing signals, and will allow the automation of demand curtailment and reduction.

First, smart grid technologies will provide retail customers with instantaneous information about their energy usage. In-home consoles will provide data for how much electrical energy is being used and where it is being used, and will also provide

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a historic record of past consumption patterns. With better information, residential customers will be able to modify their energy usage patterns to reduce consumption or shift their consumption to off-peak hours.

Second, smart grid technologies will allow utilities to send price signals to residential customers. In practical terms, this means that utilities can vary prices by the time of day or by current energy loads and send those prices to consumers on a real-time basis. Consumers can decide to use, not use, or shift consumption based on the current price of electricity.

Finally, smart grid technologies will allow the automation of some consumption curtailment. For example, homeowners may elect to allow their utility to automatically turn off some non-critical appliances for short periods of time, such as air conditioners, pool pumps, hot-tub heaters, and other similar energy intensive equipment. This will allow the utility to use fewer peaking generators and thus significantly reduce its generating costs. In return, residential customers will benefit from reduced energy costs and perhaps other financial benefits from their utility, such as rebates.

Pricing Mechanisms. A number of retail pricing mechanisms that make use of smart grid capabilities have been proposed to promote demand shifting and demand reduction, including time-of-use pricing, real-time pricing, critical peak pricing, and peak load reduction credits:

> *"The widespread adoption of smart grid technology is critical for the implementation of some retail pricing schemes."*

- With *time-of-use (TOU) pricing*, electricity prices vary by time of day according to a published and fixed schedule, which only occasional changes (similar to a bus schedule). Consumers can thereby plan their electricity consumption patterns to avoid consuming electricity during high-cost hours and shift their consumption to low-cost hours.
- *With real-time (dynamic) pricing,* electricity prices can change by the hour (and potentially by the minute) based on current demand and the utility's generating and wholesale electricity purchase costs. Real-time retail pricing will be facilitated by automation, which can track current electricity prices and adjust consumption by cycling off some appliances when prices are high.
- *Critical peak pricing* combines TOU pricing with real-time pricing. Time-of-use price schedules are used on most days, but on days when high peaks are anticipated or observed, real-time pricing is instituted to reflect the utility's high cost of providing electricity. Critical peak pricing could be an intermediate step between TOU pricing and full dynamic pricing.
- *Peak load reduction* credits are not strictly a pricing strategy but rather a load reduction program. Retail consumers and a utility enter into agreements that allow the utility to turn off power-intensive equipment during periods of peak demand. In return, the consumers receive lower electricity rates and/or rebates for helping the utility to quickly avoid high peak generating or wholesale costs.

KEY ISSUES

A number of important and potentially controversial issues surround retail pricing and the smart grid. These include consumer response to price signals, type of technology, technology adoption, and privacy issues:

- *Consumer response* to pricing signals is uncertain. It is not known if consumers will significantly change their electricity consumption patterns with better cost information or if they will respond to different pricing strategies. Electric energy costs are not a big budget item for many consumers, and so they may not be sensitive to relatively small changes in their overall budgets. Presently, consumer response to price signals is essentially unknown.

- The *type of technology* that will eventually be deployed to retail consumers is unknown at this stage. Will smart grid technology be embedded in common utilities, such as refrigerators and air conditioners? Will technology standards be set by individual companies, by government agencies, or will an "open source" paradigm evolve?
- The *widespread adoption of smart grid technology* is critical for the implementation of some retail pricing schemes. For example, real-time pricing will require smart grid technology in the home to allow appliances to be turned on and off, and to provide pricing signals to consumers. Without widespread and rapid adoption of smart grid technology by consumers, most smart grid retail pricing strategies will be ineffective.
- *Consumer privacy* is another critical issue for smart grid deployment. How much information will utilities collect about the consumption patterns of customers? Who owns this information — the consumer, the utility, or the smart grid equipment provider?

RECOMMENDATIONS

The smart grid retail pricing issues above suggest the following recommendations for the state of Colorado:

- Encourage state agencies and universities to undertake studies and experiments to better understand the consumer response to electricity pricing signals so that regulatory bodies can promote retail pricing strategies that will have the largest impact on consumers use of electricity and demand-side management.
- Remain deliberate and cautious on introducing smart grid technologies too early in the development and adoption cycle to avoid technological dead-ends and islands.
- Promote open smart grid technology standards to encourage competition, innovation, and broad participation.
- Encourage policies and strategies that promote incremental and stated penetration of smart grid technologies. Rushed investments may result in arbitrary adoption of unproven technologies further eroding consumer confidence when technologies do not work as advertised.
- Take steps to protect consumer privacy and quickly resolve who owns consumer smart grid information.

SMART GRID WORKFORCE DEVELOPMENT

Stephen Lawrence

ABSTRACT: *This chapter concerns smart grid job growth and workforce development. A survey of this topic is provided in three sections: (1) Background and Context, (2) Key Issues, and (3) Recommendations.*

BACKGROUND AND CONTEXT

Few studies have focused on smart grid job growth specifically. The most comprehensive of these is a research study undertaken by KEMA, an international energy consultancy (KEMA 2008). The KEMA report forecasts that more than 278,000 smart grid jobs will be created in the U.S. during the deployment phase of smart grid technology over the next five years, and that almost 140,000 long-term smart grid jobs will remain once smart grid is fully implemented by 2020. If the KEMA forecasts are correct, smart grid job creation in Colorado could total more than 34,000 during smart grid deployment, with more than 17,000 permanent long-term smart grid jobs.

	U.S. SMART GRID JOBS		COLORADO SMART GRID JOBS	
Employer Category	**2009-2012**	**2013-2020**	**2009-2012**	**2013-2020**
Direct utility smart grid	48,300	5,800	5,952	715
Contractors	19,000	2,000	2,341	246
Direct utility suppliers	117,700	90,000	14,503	11,090
Indirect utility supply chains	79,300	22,500	9,771	2,772
New utility / ESCO jobs	25,700	51,400	3,167	6,334
Transitioned utility jobs	(11,400)	(32,000)	(1,405)	(3,943)
Total jobs created	**278,600**	**139,700**	**34,329**	**17,214**

Colorado smart grid jobs were calculated as a fraction of U.S. jobs based on the ratio of Colorado to U.S. population in 2009
Source: Kema (2008) and author's calculations for Colorado

More generally, there are widespread expectations that the installation of "clean energy" technology in the U.S. electrical grid will create many new clean energy jobs in the U.S. economy. For example, a recent study by PEW Charitable Trusts reported that 770,000 clean energy jobs existed in the U.S. in 2007, with a 10-year annual growth rate of 9.1% (PEW 2009). In comparison, U.S. job growth was 3.7% annually over the same 10-year period. For Colorado alone, more than 17,000 clean energy jobs existed in 2007 with a 10-year annual growth rate of 18.2%. While the PEW report does not separate smart grid jobs from other clean energy employment, it does suggest the large potential for significant job growth as smart grid technology is deployed nationally and within Colorado.

No other studies are known which specifically address total smart grid job creation, but the U.S. federal government and state governments are investing heavily in clean energy job training, including smart grid training. In late 2009, the state of California awarded 34 grants worth $27 million as part of its California Clean Energy Workforce Training Program. In May 2010, the U.S. Federal government awarded almost $100 million for workforce training in the electric power sector, including smart grid training grants. The only award within Colorado was to Professor Tim Brown and colleagues from the University of Colorado at Boulder. They won a $2.7 million grant from these Federal Recovery Act funds for Strategic Training in Networking for Power Systems, a graduate program integral to the successful development and deployment of smart grid technologies.

Context

Smart Grid Employers. A significant appeal of smart grid deployment is that it is broad-based and extensive, occurring in large and small businesses across a range of industries— not just within electric utility companies. For example, smart grid job growth is forecast to occur in the following broad categories (KEMA 2008):

- Direct Utility Smart Grid Employees
  - New smart grid-skilled workers within utilities
- Contractors
  - Employees of companies that install and deployment smart grid services
- Direct (Tier 1) Utility Suppliers
  - Vendors of equipment procured and deployed by utilities for smart grid
  - Meter manufacturers
  - Intelligent Transmission and Distribution (T&D) automation device producers
  - Communications system products and services providers
  - Software system providers and integrators
- Indirect Utility Supply Chain
  - Suppliers of raw materials and finished components Tier 1 vendors
- New Utility / Energy Service Companies (ESCOs)
  - Employees of companies installing, servicing, and operating smart grid technologies (e.g., in-home devices and systems, rooftop solar energy, etc.)
  - Multiple independent firms and small businesses
- Transitioned Utility
  - Traditional grid utility workers who must transition to new jobs or will be displaced by smart grid automation; for example, meter readers.

Smart Grid Job Types. The types of employees needed by smart grid employers are as broad as the range of employers themselves. Smart grid jobs therefore represent a wide variety of educational backgrounds and skill sets, and certainly are not restricted to narrow smart grid technical specialties. Relatively few smart grid jobs will require deep knowledge of smart grid technologies. In fact, most new smart grid jobs will draw upon traditional and existing employee skills in business administration, project management, marketing, operations management, finance and accounting, information management and technology. However, as in any industry, smart grid employees of all descriptions will need to have a fundamental understanding of the utility industry and of the role of smart grid within it. The range of smart grid jobs includes the following:

- Project management
  - Project managers, executive assistants, lead consultants
- Program support
  - Schedulers, budget analysts, contracts administrators, communications administrators, legal support
- Quality assurance
  - Vendor management, test and verification, performance analysts
- Planning
  - Requirements development, case managers, telecom/communications managers; IT interface (DB, software), grid upgrades, rate planning support, marketing & outreach
- Functional support
  - Rate design implementation, marketing, public relations, revenue cycle services
- Communications installation management
- IT Software upgrades, replacement, and new applications

- Customer service (e.g., call centers)
- Implementation and operational support
  - Supply chain & inventory management; logistics; meter testing, installation, & disposal; grid component installation (e.g., transformers, closers, breakers, sensors)
- Functional specialists
  - Special metering, outage management, net metering, prepaid services, theft prevention, power management, power quality, asset management, etc.

Graying of the Utility Workforce. Another emerging factor that will play heavily on the deployment of smart grid technology is the rapid graying of the utility workforce. In a recent 2008 survey of public utilities, "more than 60 percent of the respondents believe retirements will pose either a moderate or very great challenge to their utility," and "more than two-thirds … indicated that the skilled trade positions will be among the most difficult to fill when current employees retire," followed by supervisors and engineers (APPA 2009). The need to train and employ highly skilled and educated workers in the utility industry will be both a boon and a problem for smart grid deployment. It will be a boon because accelerating retirements will drive demand for education and training in the utility industry, including smart grid technologies, which will create qualified employees. It will be a problem because a shortage of trained and experienced utility workers and the resulting competition for qualified smart grid and utility employees is likely. Those states, regions, universities, and schools that anticipate and respond to this looming shortage will be at a competitive advantage relative to those that are unprepared.

> *"If the KEMA forecasts are correct, smart grid job creation in Colorado could total more than 34,000 during smart grid deployment, with more than 17,000 permanent long-term smart grid jobs."*

Caveats. The analysis outlined and summarized above is subject to several caveats. First, the 2008 KEMA study is optimistic about the rate at which smart grid technology will be deployed and jobs created. That study assumed that federal stimulus funds would be flowing in quantity by the middle of 2009 and that job growth would accelerate quickly. In fact, stimulus funds were not available in 2009 and are only beginning to flow in 2010. The KEMA assumption that the smart grid will be largely deployed by 2013, ambitious to begin with, is already seriously behind schedule. The implication is that job growth will come more slowly and be spread over a longer interval than shown in the table above.

Second, the KEMA analysis largely focused on the deployment of Advanced Metering Infrastructure (AMI, or smart meters), and did not fully consider other sources of smart grid employment. For example, it does not include smart grid improvements to grid transmission and distribution systems, possible PHEV employment, or the economic multiplier effects of smart grid investment beyond two levels. It also does not include possible job growth from distributed generation (e.g., solar, wind) products and services facilitated by smart grid deployment. The implication is that smart grid job creation may be significantly *larger* than the KEMA forecast.

Finally, the analysis above assumes that sufficient skilled workers can be found (and found in Colorado) to deploy smart grid technologies at the rapid rate forecast. Smart grid business and jobs will flow first to those countries, states, and regions that have the educated workforce and infrastructure to take that largest advantage of accelerating smart grid opportunities.

KEY ISSUES

In quick summary, recommendations for promoting smart grid workforce development in Colorado are predicated on the following observations:

- The potential for smart grid job growth in Colorado is large, and is estimated to be 30-40,000 during smart grid deployment (2010-2015), declining to 20-30,000 once smart grid is fully deployed (2015-2020 and beyond).
- Most jobs related to smart grid will be similar to other jobs in other industries— few job types will be unique to smart grid or require specific smart grid skills. In order of job potential, smart grid employment will be in these broad categories:
    - Business management and administration jobs
    - Technical smart grid jobs
    - Engineering and scientific jobs
- Jobs will be created in businesses of all sizes— not just within incumbent utilities.
- Many seasoned utility managers, technicians, and engineers will soon be retiring and will be difficult to replace without sufficient preparation.
- Without planning, there may well be an insufficient workforce to support both the existing utility infrastructure and the development of new smart grid infrastructure.

RECOMMENDATIONS

Smart grid workforce development recommendations for the state of Colorado include:

- Encourage universities, colleges, and industry groups in Colorado to provide introductory smart grid workshops, courses, and boot camps to bring experienced business professionals up to speed with the utility industry and the role of smart grid within it.
- Encourage engineering schools in Colorado to develop and deliver curricula in power engineering with courses in smart grid technologies to train engineers and applied scientists to develop and design the smart grid/utility infrastructure of tomorrow.
- Encourage community colleges and technical schools in Colorado to develop programs to train technicians in those skills needed by utilities and other businesses to install and maintain the smart grid/utility infrastructure of tomorrow.
- Promote the entrepreneurial creation of new smart grid businesses and business units with proof-of-concept seed grants, technology transfer programs, and other entrepreneurial initiatives.

CONSUMER BEHAVIOR

Barbara Farhar, Robert J. Kemp

ABSTRACT: *This chapter concerns consumer perception and behavior issues relative to smart grid privacy and security. It has four sections: (1) Introduction, (2) Background and Context, (3) Key Issues, and (4) Recommendations.*

INTRODUCTION

From a utility perspective, the smart grid promises to revolutionize the way that transmission and energy distribution are managed. However, the experience from the consumer perspective is less clear. This chapter draws on social science literature concerning internet and smart grid-related findings in business, psychology, sociology, and information technology to sketch the state of knowledge of consumer perception and behavior relative to smart grid privacy and security.

Consumer behavior in relation to these issues is complex and difficult to predict. Real, genuine risks to consumer privacy and security will develop as a result of "smart" metering technologies that provide real-time household electric consumption data to utilities, and possibly third parties. The electrical data recorded by smart grid systems provides companies with private information of household activities. The availability of household electricity data opens the potential for fraud, sabotage, hacking, and other forms of intrusions to the consumer with potentially serious economic and even physical consequences. The possibility of potentially damaging and dangerous consequences to the consumer is raised by the use of social norming (publicizing household electricity consumption data) as a mechanism to reduce consumer energy consumption.[19, 23, 24] As a whole, consumers are probably unaware of these risks and the implications of public data releases are not well understood, indicating the need for greater and more varied understanding of the relationship between household behavior and privacy and security needs. Government policies may not be sufficient guidance for smart grid privacy problems.[25]

BACKGROUND AND CONTEXT

The background section discusses four central themes to provide a backdrop for understanding consumers' concerns relative to the smart grid: (1) Privacy, (2) Identity, (3) Trust, and (4) Energy Efficiency Responses to Feedback on Electricity Consumption.

Privacy. Privacy, especially in relation to technology, is about defining and maintaining borders. In general, people expect some degree of privacy in their daily lives, and although definitions may vary from person to person, there are shared definitions (norms) of privacy within social groups. These shared norms evolve over time, as evidenced by the advent of social networking sites, like Facebook, where large numbers of people share intimate information openly on the web. Despite changes in their breadth or extent, social norms define core borders that shape concepts of privacy and define breaches of privacy. These borders include: (1) natural borders guaranteeing physical privacy, such as doors and personal space; (2) social borders, such as confidentiality within certain social relationships, like doctor-patient or family relationships; (3) spatial/temporal borders that provide social space so that parts of our lives may be compartmentalized without sanction (for example, moving to a new town to start over and trusting that wild adolescent activities will not unduly influence later adult years); and (4) ephemeral or transitional borders, such as the bracketing of a moment of indiscretion or the expectations of temporary privacy boundaries, as with the posting of a problematic item on Facebook.[3] Although privacy norms are shared, individuals can and do set personal boundaries, and what may seem obtrusive to one person may not to another. Social norms defining acceptable boundaries and the constitution of violations of privacy are important considerations. In general, current social norms protect the confidentiality of customer utility data. Social norms relative to smart grid and privacy, however, are still developing.

Different people can view the concept of privacy differently. For instance, some people may view controlling their privacy as empowering; others may view protection of privacy as an important function of their daily lives; still others may conceive of privacy as a human dignity issue; and many others point to it as an important regulatory concern for governments.[1-3] Several important factors influence privacy perceptions, including how individuals shape their identities, the level of trust present in the social context, and socioeconomic status (where individuals with higher income or prestige are often better able to protect their privacy, while those lower on the socioeconomic ladder may be forced to trade their privacy for potential benefits not otherwise available to them).[1,3] These perceptions of privacy and boundaries shape the information that people share, keep private, and what they will consider a violation or breach of privacy if their information is used by a third party.

Identity. This section discusses two important concepts surrounding identity: economic rationality and social rationality. The idea of economic rationality hypothesizes that individuals behave in ways to maximize their economic benefit. The idea of social rationality points to other social factors, such as status and social norms, to explain human behavior.

Boundaries are central to understanding how individuals conceptualize their identities, defining where the self ends and "the other" begins. Identity is the way that individuals and groups perceive themselves and how they want or think that others perceive them. Identity is a person's conception and expression of their individuality within the network of values and convictions that structure a person's life. Personal values and convictions are shaped by social interactions and social context. Furthermore, the desire, whether conscious or subconscious, to maintain or project a particular self-identity can dictate the behaviors in which people engage. Individuals use their identities to inform their behavior as they maneuver through daily life.

Social groups set boundaries for their identities and constantly patrol those boundaries, identifying those who cross them as in some way deviant. Identity does not exist in a vacuum, but is constantly being shaped by experiences and social interactions. Individuals are motivated to pursue their goals in the most rewarding way possible.[5] Such goals, however, are based in and defined by the social context of the individual and are subject to social appraisal. Individuals often work to maintain a positive self-image when making decisions and this is partially mediated by their social context.[5] For example, if individuals live in a social context where using less energy is a social norm, then they may be more likely to use less energy to maintain their positive self-image. If consumption of energy is not a concern in their social setting, or if high levels of energy consumption are symbols of status and prestige, then individuals may not be motivated to use less or may even be motivated to use more.

The concept of economic rationality, which explains behavior on the basis of maximizing economic utility, is often used to attempt to explain or predict behavior, but this approach fails to account for frequent seemingly irrational behavior.[9] To make sense of this

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phenomenon, the concept of social rationality has been developed. Social rationality is different than economic rationality; here, individuals are seen as 'rational' in particular ways that maximize several social concerns—such as status hierarchy—when interacting with others, whereby utilizing socially-rooted shortcuts or mechanisms to gather information and act upon it (consciously and unconsciously).[9] Social rationality explains that people tend to: (1) be resourceful in that they will search for possibilities to achieve a goal, (2) be restricted in their choices through scarcity of resources and opportunities, (3) have expectations from the past, present, and about the future that they integrate into current decisions, (4) be evaluating, attaching values to past, present, and future states of their world, (5) be motivated to achieve a situation which they value more than the one they are in, and (6) attach meaning to events and ascribe meaning when the event or situation has not been experienced before using their existing knowledge and values.

These goals and methods of attainment are subject to social influences such as social norms and feedback on social status and identity implications of the decision for the person.[9] When individuals consider themselves to be in a social setting or a place where they may be surveilled, they will use social rationality to maximize their self image while achieving their goals. Social rationality will dictate which goals and actions will maximize status and other social goals that are important during periods where a person is being watched or surveilled. This activity occurs while in their social setting with all of the other individuals in that setting and is, in turn, changing and influencing this process.

At first glance, many assume that utility customers will decrease their energy consumption in accordance with economic utility. However, as noted, other motivations may come into play. A consumer may value convenience or comfort over cost savings, for example, and make no change in energy usage despite financial incentives. In terms of identity, an individual who desires to project an affluent lifestyle could choose to use energy at the costliest time of the day, instead of engaging in cost-saving behavior.

In terms of understanding consumer behavior in the smart grid context, it is essential to recognize that identity and social factors, not only economic utility, will need to be explored and understood to be responsive to consumer expectations and concerns about smart grid technologies.

> *"Trust is key to maintaining identity and in defining what a breach of privacy might mean. High levels of trust may mean that more boundaries can be crossed without it being considered a breach."*

Trust. Trust is key to maintaining identity and in defining what a breach of privacy might mean. High levels of trust may mean that more boundaries can be crossed without it being considered a breach. Trust applies to both technologies and organizations. When using technology, social norms and perceptions are the primary factors influencing the trust that a person will have. Privacy is not a guarantee when individuals interact with technology, especially in terms of the internet; therefore, trust plays a central role in the interaction between technology and the individual.[7] Pioneering work in this area has been done by researchers interested in internet security and trust. Trust in the e-commerce setting, and with technology in general, is viewed as a trade-off between convenience and perceived security/privacy.[21]

Technological trust is influenced by a number of factors, both technological and social. From a technological perspective, third-party certification of security, such as website seals of security, and privacy statements increase consumer trust.1 Four common trust indices in electronic commerce include: (1) third-party privacy seals, (2) privacy statements, (3) third-party security seals, and (4) security features, the most commonly used being privacy/security statements.[1] The Belanger study[1] also found that relative to web site pleasure of use, security and privacy issues took a back seat, indicating that the trade-off between security and other factors is heavily influenced by usefulness and pleasure of use.

Gender differences exist in likelihood of technology adoption — men are more likely than women to take up newer technologies (this is, of course, not always the case), indicating that men trust technology more than women do.[13] Similarly, older individuals tend to be later adopters of technology and less trusting on average than younger ones.[13] These differences are often associated with the social norms that accompany a person's social position, influencing the attachment that a particular group or individual may have to technology. Such attachments are another central feature in shaping perceptions of security and trust.[27] The more attachment a person feels to a technology, the greater the feeling of security with it, and the greater the impact a breach in that privacy/security border will have on security perceptions.[27]

On the organizational side, surveys on public attitudes toward utility companies in general tend to show majority favorability toward utility company performance of their responsibilities, and the public tends to consider utility companies relatively trustworthy authorities on electricity generation, transmission, and distribution.[12] Because the smart grid is identified with utility companies, public trust in them could significantly affect perceptions of smart grid security.

Feedback on Energy Consumption. The smart grid promises to bring new types of feedback to a wide range of households. This includes feedback on historical and real-time electricity consumption and social norming feedback, which uses aggregated neighborhood consumption data to provide insight into their energy behavior in a broader social context. Households and individuals are constantly receiving and processing feedback on their behavior from the environment around them. This feedback could take many forms, including physical pain if they were to injure themselves during a dangerous activity or awkwardness in the event of an interaction that was inconsistent with identity and self image. The timing of the feedback may vary as well— instant feedback in the case of pain or delayed feedback if the person did not realize until later that their interaction was sanctioned. Real-time feedback on energy consumption is a completely new experience, and the social norms concerning household consumption are currently unclear.

Many studies have examined the impact of different feedback mechanisms on household electricity consumption. A recent review compiles these results to identify the potential energy savings of different approaches. The two main types of feedback on energy consumption are indirect feedback (feedback dispensed after the consumption occurs) and direct feedback (provided concurrently with the consumption).[9] Overall, direct feedback is the most effective in reducing consumption, but there are important reductions through indirect feedback as well. Indirect methods such as enhanced billing that provides information on usage of other homes in the neighborhood as a comparison has shown an average of a 5.6% drop in energy consumption, presumably due to social conformity forces such as maintaining a positive self image and cognitive dissonance.[9]

The most effectual method in reducing consumption involved providing real-time or near real-time feedback on what each appliance was using in a home, on average reducing consumption by approximately 13.7%. This indicates the increased ability of households to reduce energy consumption when there is information on disaggregated usage and suggested solutions compared to the usual, less explicit information found in traditional utility billing.[9] Employing the ideas of social rationality, this finding makes sense; households will act to create a situation that they value more than their current one and if they can save money through small reductions in consumption and maintain their comfort levels, the value of the situation increases and they do so, particularly when it is "the thing to do" in their social groups and networks.

KEY ISSUES

Three central issues should be kept in mind as the smart grid is integrated into the current utility infrastructure: (1) Conspicuity of Electricity Data, (2) Privacy Rights, and (3) Effectiveness and Vulnerability.

Conspicuity of Electricity Data. The first issue is central to trust. In Gainesville, Florida, the municipal utility recently published online the identified monthly utility bills of all households to attempt to create a community-based social norm around conservation. The Gainesville utility does not publish real-time electricity consumption.[19]

The potential is that this may backfire by creating social embarrassment and could lead to a distrust of the city and limited effectiveness of the intervention. There are shared norms about utility data privacy; in addition, consumers will have their own preconceived notions of privacy, and these will vary. Privacy advocates may well have different views than the municipal utility, which conducted rigorous legal review before adopting the conspicuity policy to be certain that it was impervious to legal suits.

Privacy Rights. The Electronic Privacy Information Center (EPIC) has an entire section of its website devoted to smart grid issues focused on the public disclosure of data to third parties, or for use within the utility for monitoring behavior and the consequences of such actions (EPIC 2010)[1]. EPIC has been active in pressuring lawmakers to come up with new privacy laws and enhanced enforcement of these laws. Other consumer advocacy groups in addition to EPIC, such as Privacy Rights Clearinghouse, American Civil Liberties Union, Consumer Federation of America, and the World Privacy Forum, will be very concerned with the process of defining smart grid privacy norms. These stakeholder groups work separately and together to avoid the use and storage of energy consumption data to protect consumer privacy, and they present staunch challenges when these features are proposed. In fact, federal privacy legislation has been introduced to make data collection more transparent, and to restrict the type of data that can be collected without 'opt-in'.[4] The Boucher-Stearns bill is already receiving criticism from these consumer groups because of the limited nature of the consumer protection requirements, especially the proposed privacy policy, which they claim many people will not read.[6] Research indicates that privacy policies increase perceptions of security even if they are not read thoroughly, which may also be a weakness of this approach.[1]

Effectiveness vs. Vulnerability. Although peak shaving is a major goal of utilities in deploying the smart grid, consumers are more interested in energy and cost savings. Qualitative interviewing of volunteers for Boulder's Smart Grid City pilot program revealed that more detailed and immediate feedback would be welcomed and is seen as more useful to households in managing their energy use.[13] This disaggregated feedback, however, is more likely to cause greater consumer vulnerability with respect to many of the potential privacy violations indicated by the consumer advocacy groups, and violations of the borders identified by internet researchers. So, ironically, the more effective the smart grid is for the household, the more vulnerable households become to misuse of their information, such as hacking, fraud, break-in, and other security breaches.

The concepts reviewed cannot be dealt with one at a time, but must be considered as a whole because they are all closely related. Finally, the energy efficiency behavior of the study samples used in the research reviewed may differ from that of larger populations.

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[1] EPIC highlights fourteen specific areas of concern: (1) identity theft, (2) determination of personal behavior patterns, (3) determination of specific appliances being used, (4) performance of real-time surveillance, (5) revelation of activities through residual data, (6) targeted home invasion, (7) accidental invasions of the home, (8) activity censorship, (9) decisions and actions of the utility or third parties based on inaccurate data, (10) profiling, (11) unwanted public embarrassment, (12) tracking of behavior of renters/leasers, (13) behavior tracking, and (14) public aggregated searches revealing individual behavior.

RECOMMENDATIONS

The current state of knowledge of consumer behavior and security perceptions is limited. The examples cited in this chapter only approximate the type of expected reactions and issues that may occur. Unanticipated consequences of large-scale smart grid implementation will certainly occur, although the more effort to identify potential harms, the better these can be mitigated. Based on this brief review, we can make a number of recommendations, three of which are key, for future action based on the current evidence.

Key Recommendations

Safeguard consumers' utility data and information. Sufficient research and understanding of the long-term impacts of releasing identified energy data does not exist. As such, the Colorado PUC should proceed conservatively when evaluating how to release de-identified data, and only provide data in ways that do not result in the identification of customers. The Colorado PUC should not release identified data to cities and counties or other third parties as they will likely not understand the serious privacy and other ramifications associated with the usage and possession of such information. The PUC should develop a legal recourse for those wishing for greater privacy and a system to handle short-term damages for those harmed by privacy invasions.

Conduct research on consumer responses to different types of feedback and on consumer perceptions of security and safety concerning the smart grid to provide adequate background for decision-making.

Conduct research across a diverse array of groups to ensure proper understanding of population-wide reactions.

Additional Recommendations

To alleviate some of this caution, more research needs to be done, particularly with highly diverse groups of people to get a sense of the population-wide reaction to smart grid devices. This not only includes basic socio-demographic differences linked with the technical data, but also attempts to understand the relationship to smart grid devices and security concerns.

Consumers should be allowed a period of time to understand their household's feedback from the smart grid before any evaluation of public utility bill release ("naming and shaming") is considered.

In light of the lack of evidence concerning, for example, protection of vulnerable populations such as the disabled, the elderly, and low-income households in a smart grid context, the PUC should proceed cautiously with release of personal identifiable information generate by deployment of smart meters and technologies in the household.

Given that smart grid privacy standards are just now being developed on the international level, the PUC should familiarize itself with privacy standards definitions before committing Colorado a comprehensive data privacy policy for the regulated utilities.

SAFETY ISSUES IN DISTRIBUTED AND RENEWABLE ENERGY INSTALLATIONS

Aditya Kaushik

ABSTRACT: *This chapter concerns the safety issues related to the expansion of distributed energy generation, transmission, and storage technology. Increased risks include electrical shocks, falls from ladders while servicing or installing equipment, and leakage of caustic battery fluids onto operators or into the environment. This chapter presents these and other issues in three sections: (1) Background and Context, (2) Key Issues, and (3) Recommendations.*

BACKGROUND AND CONTEXT

Background

The rapid increase in population in urban areas and their energy needs, as well as the gradual reduction in dependence on non-renewable energy sources, has resulted in the adoption of renewable energy generation systems at the utility and home levels, and smart grid technologies for managing the scalable generation and distribution of electric power.[1]

Distributed power generation and transmission are important components of future electricity infrastructure.[2] Small scale end-point electricity generation systems such as solar panels and micro-turbines will provide residential homes and businesses the opportunity to generate electricity at the local level. At the same time, the maintenance and use of these systems will require increased safety procedures such as education and training of technicians and end users, and ergonomic and protective design for these systems.

Context

Over the next several years, we can expect to see a rapid increase in the number of Plug-in Hybrid Electric Vehicles, home-level solar and wind power generation systems, and electric storage batteries and charging infrastructure in homes.[3] Rapid and safe deployment of such system on a city and country basis will spur adoption of these new technologies. As with any nascent technology, the levels of awareness and education among the general public about the safety of installing and operating these equipments needs improvement.

In this chapter we point out a few of the safety concerns with the installation, maintenance and usage of smart grid and renewable energy infrastructure at the home level, and make suggestions on the prevention and reduction of these hazards.

KEY ISSUES

- The decentralized nature of a renewable-energy based smart grid shifts safety concerns from electric utility plants to consumer-level generation. The installation of smart grid and renewable energy sources in homes will require increased interaction between residents and electrical equipment for daily use as well as maintenance. Interaction with electrical appliances in daily life involves many safety hazards. The Handbook of Electrical Hazards and Accidents lists several possible safety hazards in the use of electrical appliances at homes.[5] These include electrical shocks in kitchens and bathrooms due to the proximity of water sources and electrical outlets and appliances, contact with metal stepladders while repairing electrical equipment, and chewing of electrical wires by rodents. The additional effort required in maintaining renewable energy generation equipment at homes will increase the risk of injury from electric shock due to negligence or poor design of the equipment.

- Ladder use is involved in the installation and maintenance of renewable energy and smart grid infrastructure. Solar panels and micro-turbines are installed on the roofs of buildings to increase the exposure to sun or wind and to minimize obstructions. Falls from ladders can result in serious injury and affect people of all ages. A study conducted between 1990 and 2005 and published in the American Journal of Preventive Medicine showed that during this period, the number of incidents involving injury to Americans due to falls from ladders increased by over 50%.[5] The study showed that more than 2.1 million Americans sought emergency treatment for ladder-related injuries, of which, almost 10 percent resulted in hospitalization. The most frequently reported injuries were fractures. Besides falls, the use of metal ladders while conducting repairs of rooftop electricity generating equipment without proper protection is likely to increase the risk of electric shocks.
- The production of electricity from renewable intermittent energy sources at the residential level might require storage systems such as batteries in homes. Lead acid batteries contain lead plates and an electrolyte consisting of dilute sulfuric acid. The reversible chemical reaction in Lead/Acid batteries can be used to store and retrieve electrical energy. Handling and transport of these batteries could result in leakage of the acid electrolyte causing damage to the handler. Electrical shocks due to contact with both terminals of the battery are also cause for concern.

RECOMMENDATIONS

In order to reduce the risk of electrical hazards and accidents due to the issues mentioned above, we recommend the following measures.[6]

- *Installation by trained professionals:* as in the case of roofing repairs, installation of rooftop renewable energy equipment by trained professionals would minimize the risk of injury to the end-user. There is a need for standardization of installation procedures and additional safety measures such as stairs with hand-rails instead of metal stepladders, and insulated platforms for repair and maintenance.
- *Training and education on safety procedures for end users:* after installation, the end-user should be thoroughly trained in the identification of various components in the system, distinguishing the exposed live parts of the system from the other parts of the system, and use of protective footwear and grounding equipment while repairing electrical equipment.
- *Protective fire retardant enclosures* should be used to minimize damage due to electrical fires or leakage of chemicals from batteries. Adequate clearances should be provided for maintenance of these equipments. Sealed, leak-proof batteries should be considered to prevent injuries from chemical leaks.

COLORADO EMERGENCY SERVICES AND ENERGY ASSURANCE PLANNING

Puneet Pasrich, Arun Gerra

ABSTRACT: *This chapter focuses on emergency services and how they will be integrated into and impacted by smart grid infrastructure. The chapter consists of two sections: (1) Background and Context and (2) Recommendations.*

BACKGROUND AND CONTEXT

Currently, a general lack of technological sophistication prevents Colorado's emergency services technology from being effectively integrated into smart grid systems.[1] Moreover, until appropriate smart grid regulations and interoperability standards are defined, it will be difficult to determine how to safely integrate emergency services into the smart grid. To ensure the safe, secure, and efficient integration of emergency services into the smart grid, Colorado should develop a plan to address all possible emergency situations and a method to provide power to critical facilities during periods of power disruption.

Scope of Emergency Services

In this chapter, Emergency Services include any:

- 1st responder
- 1st responder facility
  - Fire station
  - Police station
- Emergency and Disaster Coordination entities
  - Municipal, County, State or Federal organizations that coordinate with each other and 1st responders in delivering emergency services
- Life/safety and property support entities
  - 911 call centers
  - Hospitals
  - Consumers with lifesaving equipment at home
- Government and businesses which provide infrastructure support to impacted areas
  - Damage assessment
  - Structure and utility repair
- Lifeline restoration entities
  - Communications companies
  - Public Works departments

Vulnerability of Emergency Services

Provision of emergency services for day-to-day emergencies like car accidents or structure fires are done using traditional, commercially powered sources primarily derived from fossil fuels. As the scope of these emergencies is localized with little impact to the energy system, these emergencies are handled adequately.

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[1] Interview with Boulder Communication Operations Center 2010.

Emergency planners are also focused today on the consequences of disasters and catastrophes where large areas are impacted, fatalities or injuries are wide spread, utilities including power, fuel, and communications are severely limited or unavailable.

Emergency Services Coordination centers (i.e., Emergency Operations Centers operated by state, county, municipal, and federal government agencies) in most cases have implemented mitigation measures for loss of commercial power during a disaster or catastrophe in the form of diesel generators to power facility computers, lights, and communications equipment. The vulnerability in this case is that an incident could impacting the supply of fuel for generators. If the outage continues for a number of days and is beyond a localized power outage restored through business-as-usual operations by commercial power utilities, it will shutdown the coordination and communications ability of the Emergency Operations Center.

> *"Currently, a general lack of technological sophistication prevents Colorado's emergency services technology from being effectively integrated into smart grid systems."*

Outside of the Emergency Operations Centers however, there is little mitigation against supply shortages of fuel for emergency services vehicles. Maintenance costs and budgets have reduced or eliminated the amount of emergency services controlled stores of fuel beyond vehicle and generator fuel tanks. Many of these services now rely on commercial supply of fuel. While government entities can control the supply and use of fuels during an emergency, there is little that can be done if the continuous supply that is assumed to be in place is disrupted for more than a week. Given the requirements and conservative nature of emergency services decision makers, it is not expected that police cars and fire trucks will embrace hybrid technologies in the near future.

Outage Management

Along with tornados, earthquakes, wildfires, chemical spills or fires, floods, droughts and other disasters that Colorado emergency planners respond to or address through planning and exercises, sustained power outages is an incident that has growing concern given the 2003 outage on the East Coast.

A sustained power outage is of particular concern for emergency planners at all levels of government as the community is largely unprepared for it. Heating and cooling systems use a combination of natural gas to generate heat and electricity to distribute it throughout the structure, be it residential or commercial. The extremes of weather in Colorado combined with a loss of commercial power would leave vulnerable populations (i.e. aged, infirmed, new born, chronically ill) at risk in a short span of time.

To address these incidents, emergency planners need to embrace the solutions that smart grid technologies provide to maintain the energy requirements of emergency services throughout a long term disruption to commercial power. Use of diesel powered generators, a form of distributed generation, to power Emergency Operations Centers is a move in the right direction however, and as stated earlier; it is primarily addressing short term disruptions to commercial power.

Emergency Planners need also to address the unavailability of fuel for emergency services vehicles during a sustained outage. While sufficient supplies of fuel may be available, underground storage tanks require commercial power, or generators if available, to pump fuel to delivery trucks and retail distribution points require commercial power to distribute it to consumers, which includes emergency services vehicles.

Development of an outage management plan to ensure energy supply during an outage is a key responsibility of state, county, municipal, and federal emergency planning agencies. The state of Colorado and a small number of municipalities have received ARRA funds to develop such energy assurance plans. They propose to engage consultants to assist in the development of such plans. These energy emergency planning efforts are by no means easy. They involve collaboration and cooperation between one entity that is responsible for the citizens and the community and the other is often a commercial entity with responsibility for shareholders and turning a profit. Often the objectives and methods are at odds.

RECOMMENDATIONS

Suggested steps to develop an energy assurance emergency plan

Step 1 – Establish Guiding Principles

- The first meeting will be used to define the guiding principles in developing the Energy Assurance Emergency Plan. By involving energy emergency experts in the stakeholder workshop, the intent will be to resolve issues and accurately answer any questions about current capabilities, policies, or procedures during the workshop. While a meeting/workshop format is proposed, the managers should employ webinar presentations, surveys, phone interviews, conference calls and other means that will encourage involvement from a wider range of stakeholders.
- Buy-in and participation by stakeholders is essential in developing the plan.
- Information and capabilities shared in workshops, meetings, and other communications shall be considered confidential and proprietary and restricted to those in the plan development process.
- The basis is that the current level of assurance will be improved through cooperation, information sharing, and critical thinking.
- That policies and procedures in both the public and private sector impact the full realization of a comprehensive and effective energy assurance emergency plan.

Step 2 – Determine Public And Private Sector Responders

- It is important to identify the responders in both the public and private sectors to ensure they are included as stakeholders and to gauge their level of knowledge skills and abilities in the area of energy emergency response.

Step 3 – Present Realistic Scenarios That Will Test The Response Of The Public And Private Sector

- Scenarios are a proven method for testing and exercising capabilities of response entities. The initial scenarios are used to extract weaknesses and gaps in stakeholder plans and capabilities. These will be collected in a constructive manner without criticism or highlighting of stakeholders deficiencies. The primary scenario concerns of key stakeholders will figure prominently in the early stages of this project as well as the design of further training/exercises events.

- During the early stages, scenario based discussions help clarify concerns, expected cascades and relationships, primary and secondary roles and responsibilities (which may vary based on the scenarios), procedures, possible strategies, and policy options for response and recovery.

- Based on these discussions, the managers will work with the state, county, and local planning agencies, the GEO, PUC, Colorado Department of Emergency Management, and industry stakeholders to identify the highest priority scenarios to support the intra- and inter-state training/exercise events.

- Concurrent exercise development and long-term scheduling encourage broad stakeholder exercise participation.

State Recommendations

- Partner with Colorado counties and municipalities in utilizing distributed generation technology including backup communication, in case there is a power outage.

- All emergency communication centers in Colorado should have backup plans for power to run their services. In case there is a power outage, communications should not be effected. At least 2-3 weeks of power should be stored in backup systems.

- Communication backup plans should be defined, in order to prepare and respond to man-made emergencies, terrorist attacks, or natural disasters.

- Priority for back-up-power supplies should be given to 911 services, hospitals, fire and police stations. As such, it is best to isolate these services from the main power grid and to provide them with their own separate communications channel and power distribution methods. These channels should be planned with security in mind and the probability of failure should be estimated.

- Enable power to be routed from other regions in the WECC, if possible to do so.

County and Municipal Government Recommendations

- Review the capabilities of distributed generation and how it supports emergency services for their jurisdiction.

- Validate energy supply priorities with utilities, fuel supply, and consumer distribution to ensure that essential services including hospitals, aged care, communications, and emergency operations centers are available.

- Engage in an effort to perform energy assurance planning in cooperation with surrounding jurisdictions, utilities, and the state of Colorado.

- Explore techniques for emergency services vehicles to be powered from Distributed Generation sources.

- Ensure that emergency services communications, emergency operations centers, and other critical emergency service facilities develop distributed generation plans that support a long term outage of commercial power.

Utility Recommendations

- Develop emergency backup plans.

- Specify to public the expected downtime for any power outage and how much time might be needed to repair facilities in the event of a particular emergency situation.

- Establish incident response plans for particular threats and the systems that would be compromised.
- Support efforts in the public sector to develop energy assurance plans through such efforts as building in-house expertise, working with experts, information sharing, and exercise participation.
- Identify critical assets which can be compromised via communications channel or the internet and how to protect or back up those systems.
- Logical security and physical security should be in place before implementation of the smart grid, or integration with other technologies for critical facilities.
- Utilities should isolate power distribution for emergency services from the public network because isolation is the key to protecting the smart grid.

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