7. Energy Sector

7.1. Introduction

The aging United States infrastructure is a major issue for all communities nationwide. Although we have made progress in upgrading the existing electric infrastructure to a smart grid, grid modernization improvement is projected to continue for the next 25 years. The demand for electricity has increased by over 25% since 1990, intensifying our need to upgrade all elements of the energy infrastructure system and build for resiliency. In addition, the role and responsibility of utilities is evolving, with far more energy efficiency, Demand Side Management, MicroGrid, and Smart Grid technologies vastly influencing a change from a function that is purely energy distribution to a more complex and interdependent energy transfer and tracking role. In an effort to build a resilient and flexible energy infrastructure there needs to be an understanding of the desired level of resilience, the potential changes resilience may bring, and the anticipated cost to accomplish this effort.

7.1.1. Social Needs and System Performance Goals

As communities address issues related to their expectations of energy sector performance, improving grid resilience, and the costs associated with those improvements with the utilities, there will be a focus across the nation to understand the needs of the consumer (public safety, hospitals, businesses, and residences). Systems need to have the ability to adapt to the ever-changing environment and be built to either minimize damage and impacts to the system or rapidly rebuild the system after significant events and disasters occur. There needs to be an encompassing effort to enable the various utilities, municipalities and co-operatives across the country to maintain the system while controlling costs. Because some utilities are operating in a competitive environment, they must find the lowest cost alternative while not impacting the overall network resiliency.

There is also a need for consumer education to discuss costs and benefits of facility and infrastructure hardening along with reasonable expectations of performance. Generation facilities and substations may need to be relocated into the communities they serve to ensure these facilities are sited and constructed to be resistant to coming hazards (e.g., flooding, storm surge, wildfire, etc.). Important conversations must take place to identify intended vs. expected performance and understand the costs and impacts of providing a reliable and resilient Energy Sector to minimize the impact to communities after all types of events.

If major changes are required to address the consumer expectation of readily available energy, fuels, and power after events (minor, major, and even catastrophic events) new community partners must be brought to the table.

7.1.2. Reliability vs. Resilience

Reliability and resilience are related, but distinct, concepts with different performance goals or metrics. In many cases, the projects and investments being made to improve day-to-day reliability contribute to resilience, however there is not a one-to-one correspondence. In August 2012, the President's Council of Economic Advisers released a study on the benefits of investing in grid resilience. The study explained the difference between resilience and reliability as:

> *"A more resilient grid is one that is better able to sustain and recover from adverse events like severe weather – a more reliable grid is one with fewer and shorter power interruptions."*

To explore some of the differences between reliability and resilience, we can look at recent events. In the wake of Hurricane Sandy, widespread power outages had cascading and disastrous consequences across the New York and New Jersey region, but specifically in lower Manhattan in New York City. "[It was] the largest storm-related outage in our history," according to an October 30, 2012, press release from John Miksad, Senior Vice President for Electric Operations at Consolidated Edison. The tidal surge triggered flooding at a substation in lower Manhattan that knocked out power for customers below 39th Street for nearly five days.

The lights in lower Manhattan were hardly back on before Consolidated Edison asked state utility regulators to approve a very large, multi-year capital investment program to harden the electric power grid for future storms. Note, by comparison, the funding investment for resilience hardening to the funding investment by Consolidated Edison for reliability over the same period of time (taken from Pentland 2013) shows that reliability is programmed and funded at a higher levels at this utility.

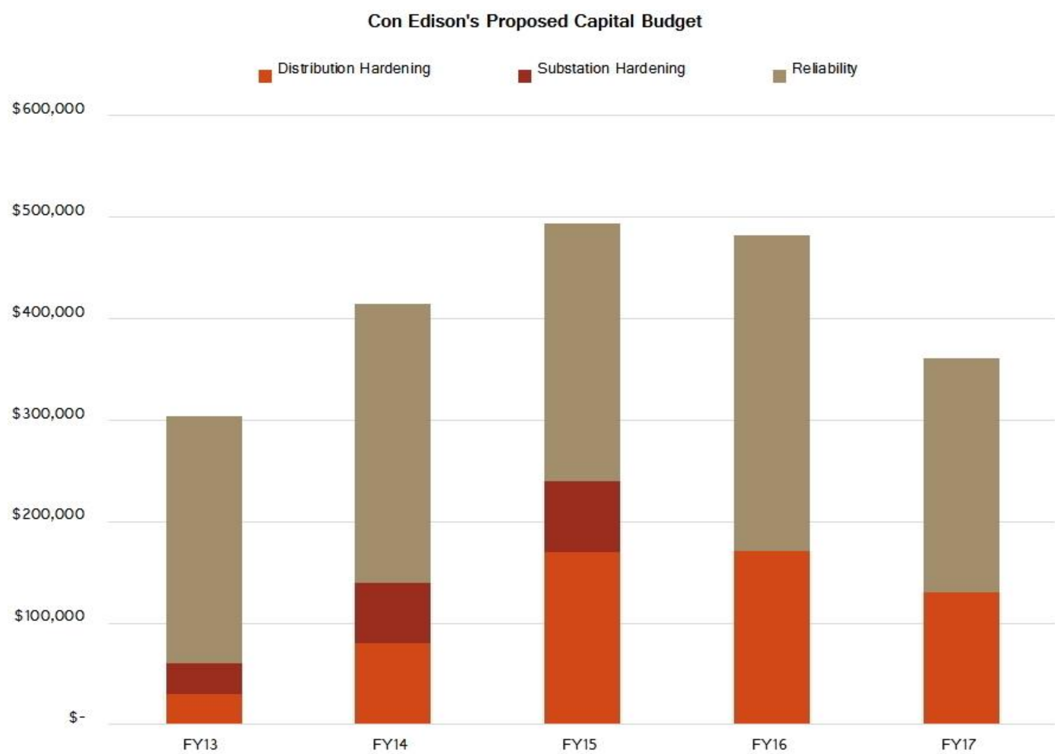

Figure 7-1. Con Edision's Proposed Capital Budget

[Note to reviewers: This table from Pentland does not seem accurate on the $$ side. One would think this spending is in 100s of Millions, not hundreds of thousands. This will be verified further for the next draft.]

This spending demonstrates that even a very large commitment to hardening is still not at the same levels as reliability spending for this one entity. Is this a trend? Is it representative of the sector as a whole? The answer to both questions is "no," but the spending plan is a recent example to help our understanding of these two initiatives. Reliability can be stated to be a "core goal" of electric service and it can be argued that resilience is a new and growing goal but is secondary to reliability. There is no clear formula to designate the appropriate balance between the two and assigning or measuring expenditures as attributable to only reliability or resiliency is not always easy to delineate: for example reliability expenditures, particularly in automation of operations, positively benefit resiliency so where should these expenditures be tracked?

Other utilities in the sector are also considering the challenge of resilience. In September 2012, Maryland's Grid Resiliency Task Force adopted similar definitions for "resilience" and "reliability." "[R]eliability [was defined] as the ability of the bulk power and distribution systems to deliver electricity to customer during normal 'blue sky' operations. . . . Resiliency was defined as the ability of the distribution system to absorb stresses without experiencing a sustained outage."

PSEG is also looking at resilience and, states in its Energy Strong Program, "Reliability remains fundamental but is no longer enough now that extreme storms have become increasingly common and people are more dependent on electricity than ever before." PSEG is looking for a different set of performance metrics for all conditions, performance metrics that have commonality with resilience metrics presented in this Chapter.

For the purposes of this framework, NIST will use the definition of "resilience" from Presidential Policy Directive/PPD-21: Presidential Policy Directive – Critical Infrastructure Security and Resilience:

> *The term "resilience" means the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents.*

Quantitative statistics have not yet been compiled to illustrate the effort that the Electricity Sector has put into resilience, but the sector has thought a great deal about resilience. In recent industry studies (NARUC 2013), NERC defines resilience of the bulk electric system via two main responsibilities – adequacy and security. NERC defines adequacy in this context as "the ability of the bulk power system to supply the aggregate electrical demand and energy requirements of the customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements." It defines security as the "ability of the bulk power system to withstand sudden disturbances such as electric short circuits or unanticipated loss of system elements from credible contingencies." This definition of security may be applied to the bulk electric system, but it is not applicable to the distribution system, nor does it address infrastructures of other sectors such as gas/fuels, telecommunications and water.

The purpose of this discussion is not to resolve the issue of which term is most appropriate or which approach will best make the infrastructure of the grid less susceptible to damage and outages during all types of events. Rather, the purpose is to look at the infrastructure elements of the Energy Sector (generation facilities, substations, transmission and distribution elements) and provide guidelines and performance objectives for design and construction of an electrical grid that is more reliable and also more hazard resistant so as to perform with the least impact or interruption when events (routine, expected, or extreme) occur. Using the terms related to resilience that are used by the other sectors will make it easier to define performance metrics for resilience in this and the other sectors and allow us to identify and understand interdependencies between the different sectors. Sections 7.7 and 7.8 have additional information regarding the relationship of reliability and resilience and what tools could be developed to aid in understanding and measurement of resilience in the Energy Sector.

7.1.3. Interdependencies

The infrastructure in each of the critical infrastructure sectors in this framework can be considered both independent from the other sectors and dependent on those sectors. Most, if not all other sectors presented in this framework depend upon the Energy Sector for the required power to provide a functioning level of resilience within their sector. For example, although a hospital or emergency operations center may not be physically damaged by a hurricane, flood, or earthquake (a resilience success in that sector), it still may not be functional without power or electricity for sustained and complete operations of all systems and services (presuming the emergency and backup power systems on site have limitations on the duration and the number of systems they can power when electricity from the grid is unavailable).

For the Energy Sector, the infrastructure that comprises the generation facilities, substations, transmission and distribution elements of the electrical subsector; the drilling/processing, transmission, distribution, and dispensing stations of the natural gas subsector; and the drilling/refining, transmission, storage, transportation/distribution, and dispensing stations of the liquid gas subsector all have elements that can be designed and constructed to perform independent of other sectors (with only a few exceptions). However, there are dependencies. If another sector's assets are damaged, the Energy Sector will be impacted and the measure or effectiveness of the sector's resilience may be reduced. Some examples are:

1. If the transportation of liquid and natural gas over land (via truck and rail) is not possible, then the supply chain can be effectively stopped (depending on the severity of damage to the transportation sector from a specific event), which affects the resilience of the Energy Sector.
2. The resilience of the Electrical Subsector is based not only on whether the physical elements of the sector can resist the effects of a flood, wind, seismic or other events, but also on whether response teams, who are integral to the recovery (and resilience) of the Electrical Subsector, can mobilize and reach impacted areas. If they cannot perform response and recovery activities, the Energy Sector will be less resilient because damaged system elements cannot be reached or repaired.
3. Also, operations and control centers of utilities must be able to communicate with and send operational direction to the generation, transmission, and distribution components within the grid. While the deployment of automated systems to control the switches and controls within the grid will improve resilience, operational control must still be maintained at some level or the resilience of the grid will be affected.

Where possible, interdependencies including but not limited to those presented here, have been considered in preparing the performance goals presented in Section 7.3.

7.2. Energy Infrastructure

Our national infrastructure systems are designed for reliable service with some intention to building a stronger system due to potential disasters. While these systems are designed to minimum NESC codes (and in many areas, beyond the minimum criteria set forth in the codes), the level or magnitude of the event these systems can withstand without damage is not clearly defined. Over the years, improvements in technology have addressed some vulnerabilities or risks in the system [Note for reviewers: example of the vulnerabilities and risk that were identified will be included for the next draft.]. However, these improvements in technology may have also inadvertently introduced new vulnerabilities or risks. Recent post-disaster studies and reports on climate change have shed light on why we see the damage and impacts to these systems from the natural hazard events of the past several years.

Our task now is to address what we consider to be the basis for design and performance of the critical components of the energy infrastructure. We need to address:

1. Why did failures occur?
2. Were the design criteria not correct to account for these storms?
3. Can and should higher criteria be used? Or were these recent storms truly rare or extreme events for which it is not feasible to design the systems to resist with minimal to no impact to the services they provide?
4. Was the extent and impact of the failures disproportionate to the magnitude of the event that occurred? And if so, was the degree of the failure or impact due to the design and construction of the infrastructure or was it a result of, or exacerbated by, the inability to respond/repair the damage that was caused by the event (i.e., a poor operational response)?

These important questions need to be discussed and answered to create a framework that provides design and construction guidance in the Energy Sector so generators, distributors, and users of the bulk power system can set and achieve performance goals. The performance metrics discussed in this guidance must be discussed in a common vocabulary by both providers and consumers within this sector to have a chance to reduce our risk and increase our resilience from these different threat and hazard events.

7.2.1. Electric Power

The electric power subsector provides production and delivery of electric energy, often known as power, or electricity, in sufficient quantities to areas that need electricity through a grid connection, which distributes electrical energy to customers. Electric power is generated by central power stations or by distributed generation. The other main processes are transmission and distribution. This was illustrated in the *NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 2*.0 and is shown below.

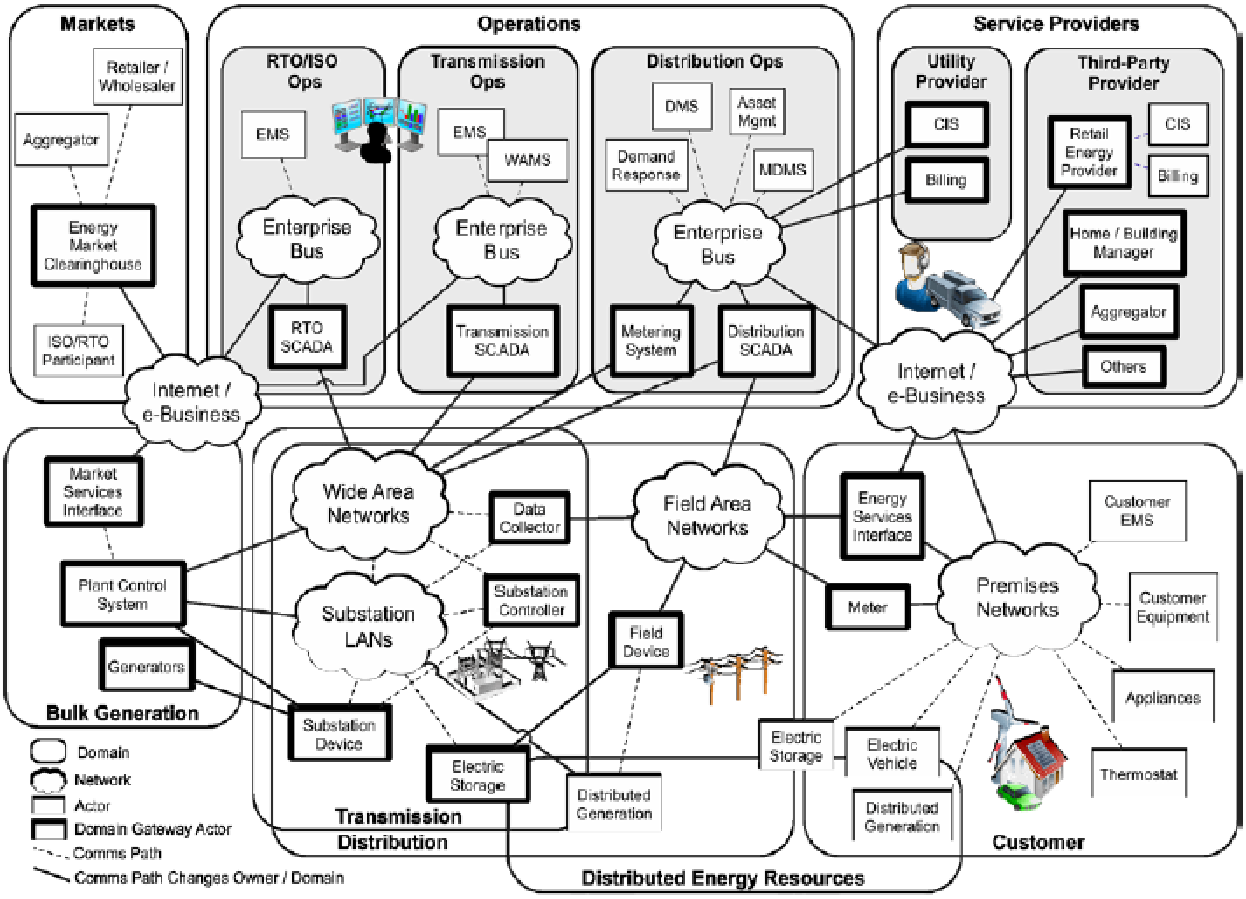

Figure 7-2. Conceptual Diagram of Smart Grid Information Networks (NIST 2012)

Many households and businesses need access to electricity. Demand for electricity is derived from the requirement for electricity to operate all aspects of our lives including providing for our health and welfare, hospitals, critical facilities, industry, as well as commercial and residential use.

7.2.1.1. Generation

Similar to the changing landscape for utilities in general, the generation system is evolving and has been for some time. Prior to deregulation of electricity in certain US states, the public utilities owned and managed both the generation (power plants) and the transmission grid over which electricity was conveyed to the public. In that regulated public utility role the utilities forecast and managed both the generation and distribution of electric power. With the advent of deregulation, many states separated the governance role that the utility had over both generation and transmission, with most deregulated states allowing independent power producers (IPPs) to competitively develop generation projects. The term "deregulation" does not imply these utilities are not highly regulated, simply that consumer choice exists, though even the IPP developers must still negotiate contracts to sell the power to the utilities who maintain their responsibility to manage and convey the electricity via the transmission grid. States that deregulated in this way also required the utilities to divest the generation assets they had previously controlled. A few states flip-flopped that role and maintained authority over generation assets and divested the transmission assets instead. Those states allowed competitive transmission providers to distribute electricity to the public and the utilities to manage the generation (power plants). The US today is a patchwork of regulated and deregulated states so, depending on the state, the utility could control both generation and transmission, only transmission, or only generation. To complicate matters further, the number of deregulated states has increased over time. Also, this patchwork of regulation and deregulation at the state level also applies to the distribution of natural gas by utilities.

Now, overlain on that already changing landscape, the US is seeing increasing development of renewable power projects, distributed generation by commercial entities, and an increasing push for demand-side management (such as demand response and energy efficiency and energy storage). Today the term "generation" increasingly includes "virtual generation," resulting from the use of load-reduction to offset power demand or the use of storage during off-peak times rather than developing new generation (power plants). Additionally, more of this activity is evolving to be behind the meter at homes and businesses (rooftop solar, smart meters, etc).

Renewable power comes in many forms – wind, solar, biomass, hydropower. In some states energy-from-waste (waste-to-energy) plants also meets the definition of renewable power. The public is well-versed in the term "renewable power," but does not typically understand that the rules vary from state to state in the same way the Renewable Portfolio Standards (RPS) or goals for the percentage of power to be generated from renewables vary by state.

"Distributed generation" is an umbrella term typically describing power plants developed for a specific company or industrial location, also known as "in-the-fence" power that serves the needs of a particular commercial plant, manufacturing facility or industrial park. These plants must be developed in accordance with requirements for their particular state, but are typically single or small group load-serving entities. An example might be an industrial facility that builds its own on-site power plant to serve its electric power supply needs. Often these generating plants are also cogeneration facilities, providing steam for a host establishment or a neighboring industrial/commercial facility for heat or another industrial process use. Many of these smaller facilities are also referred to as Combined-Heat and Power or CHP plants.

In regulated states Demand Side Management (DSM) is best defined by the Energy Information Administration: "the planning, implementation, and monitoring of utility activities designed to encourage consumers to modify patterns of electricity usage, including the timing and level of electricity demand." Thus DSM can include both Energy Efficiency (EE) or Demand Response (DR) to reduce electric demand.

Energy Efficiency at the utility level is a method or program by which the utility manages or reduces the demand for power rather than building or contracting for new generation (power plants). These programs can be high-level state-wide improvements to public buildings (efficient light bulbs, improved insulation, etc.) or can entail the distribution of energy efficient light-bulbs or sophisticated meters and thermostats for residential users.

Demand Response (DR) is sometimes implemented by a non-utility company that enters into a contract with electric users, usually large users such as universities, high-rise office buildings, chains of retail stores etc., and pays those users for the rights to require them to lower their electric use during times of peak demand such as hot summer days. In doing so the DR company sells that reduced-load to the utility during peak demand periods. This allows large users of electricity to lower their annual electric costs via the DR payment and allows the utility to avoid brown-outs or black-outs and avoid the need to develop new generation. The DSM firm makes money by selling the load reduction or a form of virtual generation to the utility at times when electricity pricing is at a premium.

Energy Storage comes in many forms, from large-scale batteries, to pump storage, to fuel cells. In the case of pump storage, which has a long history, water is pumped up to a dam or holding basin during periods of low electric demand (non-peak-periods) so it can be released during periods of high demand to meet load. This historical use of pump storage is now being expanded to use compressed air and other technical methods of delayed release of energy during peak periods.

As noted earlier, the belief that generation satisfies electric demand is only partly true. Using alternative methods to reduce, offset, or delay peak electric demand plays a larger role and, as such, needs to be considered as a key part of the system by which we ensure reliable and efficient power to the US population. To best inspire, protect, and ensure reliability one must first understand the implemented regulations by which this complex network is balanced. That understanding begins with the utilities and the state public service commissions that regulate them. The utilities themselves (even in deregulated states) are heavily regulated at the state level, and beyond. As noted previously, the term "deregulated state" has more to do with consumer choice or establishing a competitive market for power or transmission.

7.2.1.2. Transmission

The overarching issues surrounding the vulnerabilities of the transmission infrastructure stem from the aging physical assets today. As overall customer load requirements grow and the various federal and state regulations change, there is a need for more robust and flexible electric power delivery systems to keep up with demand. The emergence of the renewable generation market, and the transition from coal generation to natural gas generation, has begun new stresses on the power grid beyond its original design. Electrical flows that were once designed to be in one direction are now in multiple directions, depending on the generation available at any particular time of day. Transmission constraints, which affect cost and reliability, have become common in operations.

Although the electrical industry started with rapid innovation and expansion, it has become an industry that typically resists change and has changed very little over the last 75 years. However, transmission planning has evolved from relatively few new transmission lines being built nationwide to many new transmission lines being planned by most major utilities over the last 10 years. The cost and time to build new transmission lines have also increased significantly over the years due to public routing, regulatory and environmental restrictions.

All of these demands impact electric transmission system reliability. Ever-increasing cyber-based monitoring systems are being developed to reduce the impact of any potential natural disaster, such as hurricanes and flooding. As the intensity of storms are predicted to increase, so does the structural requirements of the transmission assets.

As new systems are engineered and constructed there is also a need to evaluate ongoing maintenance. As with any engineered infrastructure, every transmission line has a design life span, and the number of older lines that need regular assessment to maximize the use of each asset constantly increases. There has also been an alert issued by NERC in 2011 to validate the electrical clearances of the existing infrastructure in the in-situ conditions.

Many efforts are underway to strengthen our nation's transmission systems. Several major Smart Grid transmission projects have been initiated and, in some cases, recently completed in an effort to supply power across the nation. Other efforts to increase the power grid's resiliency and efficiency include developing and deploying new technologies (e.g., Demand Response, Micro-grid/Islanding, Synchrophasers (PMU), Dynamic Transfer, Energy Imbalance Markets (EIM) and Dynamic Line Rating (DLR)). The FERC also issued Order 1000, meant to reduce capital costs of transmission for end consumers by introducing competition between utilities and transmission developers

7.2.1.3. Distribution

Given the aging infrastructure, some real vulnerabilities exist in the energy sector distribution systems. The distribution systems are typically built and constructed along roadsides but, in some cases, they run through less accessible back lots and other right-of-ways. As overall customer load requirements grow, and the changes in regulations continue, there is a need for more robust electric systems; but the ability to provide these robust electric systems is struggling to keep up with the demand.

Maintaining the designed distribution systems is also a challenge. The poles and equipment that are key elements of the distribution system are subject to overloading with additional wire and system components by local service provides who add lines and equipment to existing poles. These additions may directly overload the components that make up the electrical system or increase their vulnerability to wind and ice during storm events.

Further, as new systems are engineered and constructed there is a need to evaluate the ongoing maintenance. One element of maintenance in the forefront along the distribution system is tree coverage. Most, if not all, utility entities have well established and adequate tree management programs; but failure to implement these programs has been a leading cause of outages. The reason for this failure is not always simple. Many land owners will not allow removal of any trees or limbs. Other jurisdictions and environmental entities (state, local, or activist) have also succeeded in stopping tree trimming and clear programs. The aggregate impact of these actions results in failed implementation of the tree trimming programs, which creates a critical failure point where system vulnerability continues to worsen instead of being mitigated.

As was discussed for transmission, many cyber-based monitoring systems are being developed annually to reduce the impact of any potential natural disaster such as the hurricanes and flooding.

Many efforts are underway to strengthen our nation’s distribution systems. There are major feeder hardening program/projects underway all across the nation. These projects have been focusing on dead-end cross arms, lightning arresters at any identified weak points. In California there is a push for strengthening the systems from fires. They are now “boxing in” fuses so that no hot metal will hit the ground and potentially cause any fires. Dependent on the location nationally, there has also been a movement away from wood poles. Where the wooden poles are still being used, they are increasing the size and class to accommodate the overall design constraints.

7.2.1.4. Emerging Technologies

Many smart grid technologies available today are targeted to help the electric utility significantly in improving reliability, operating efficiency, and power quality, and in identifying potential opportunities to harden the current circuits from a resiliency standpoint. Many of the technologies, considered “plug and play,” have been working together nicely with the right infrastructure. Many utilities are currently evaluating their smart grid plans and working on full integration to allow for predictability as well as corrective action.

Technology has also allowed the utilities to rapidly correct power outage situations. Many utilities across the country have implemented some form of distribution automation with very good results. These results have led to further technological advancements, which are being implemented today. Today’s utilities recognize the real need to build a resilient, safe, and economical electrical network. As the utilities computerize the electric grid, they are opening up additional opportunities for predictability and better understanding of communities’ usage.

7.2.2. Liquid Fuel

The most common liquid fuels are gasoline, diesel, and kerosene-based products such as jet fuels, which are each produced from petroleum. Other liquid fuels include compressed natural gas, liquefied petroleum gas (LPG), synthetic fuels produced from natural gas or coal, biodiesel, and alcohols. For resiliency, liquid fuels are critical to back-up power generation and nearly all modes of transportation. In addition, 11% of U.S. homes rely on heating oil or propane, with heating oil usage concentrated primarily in the Northeast and propane usage concentrated in rural areas (USEIA 2009).

Although less than 1% of all electricity in the U.S. is now generated in oil-fired plants, there are some isolated markets in which petroleum remains the primary fuel. The leading example is Hawaii, where more than 70% of electricity generation is fueled by petroleum (USEIA 2014a).

Potential failure points for liquid fuel production, storage, and distribution include:

1. Catastrophic loss of major production fields
   - Fires
   - Blowouts
   - Spills
2. Transport of crude oil from production sites to refineries
   - Ports
   - Pipelines
   - Rail
3. Processing at refineries into finished products
   - Onsite storage of raw materials
   - Onsite piping
   - Processing reactors vessels
   - Power supply (grid or backup)
   - Onsite storage of finished products and by-products
4. Transport from refineries to regional distribution centers
   - Ports
   - Pipelines
   - Rail
5. Storage at regional distribution centers
   - Aboveground tank farms are the most common storage systems used at permanent depots
6. Regional distribution
   - Pipelines (e.g., pipeline from Oregon's CEI Hub to Portland International Airport)
   - Trucks (e.g., distribution from Port of Tampa to Orlando-area fuel stations)
7. End user or retail sale
   - Onsite storage (e.g., above ground tanks at an airport or buried tanks at a retail fuel station)
   - Power for pumps at retail distributors (e.g., New Jersey retail fuel station grant program described below in Section 7.3.4)

Maintaining production of crude oil and safely transporting it to refining centers (Steps 1 and 2) are major national and international security issues that are beyond the scope of this framework.

US refineries (Step 3) tend to be geographically concentrated and operate at 90% or more of capacity during periods of strong economic growth (USEIA 2014b). The reliability and resiliency of US refinery capacity is both a national security issue and a major regional economic issue in those areas of the US where refinery capacity is concentrated.

Regardless of where production and refinery capacity are located, all communities should assess their resiliency with respect to Steps 4-7. Damage to ports, tank farms, pipelines, railways or roadways can cause serious delays to the distribution of liquid fuels which, in turn, can lead to loss of backup power generation when onsite fuel supplies are exhausted and disruptions to all modes of transportation. In cold weather scenarios, an extended disruption to heating fuel supplies also has the potential of becoming a significant issue.

Steps 4-7 are the main focus of the energy portion of the Oregon Resilience Plan, which was developed for a magnitude 9.0 earthquake scenario on the Cascadia subduction zone. The Oregon study identifies the northwest industrial area of Portland along the Willamette River as Oregon's Critical Energy Infrastructure (CEI) Hub. More than 90 percent of Oregon's refined petroleum products pass through this six-mile stretch along the lower Willamette River before being distributed throughout the state. For the Cascadia earthquake and tsunami scenario, potential hazards to liquid fuel storage and distribution networks include ground shaking, sloshing, liquefaction, lateral spreading, landslides, settlement, bearing capacity failures, fire, or seiches in the CEI Hub area and tsunami damage at the coast. Fuel is transported to the site via a liquid fuel transmission pipeline from the north and marine vessels. Alternative modes of transporting fuel from the east or south or by air are very limited. Key recommendations for improving the resiliency of the Oregon energy sector include conducting vulnerability assessments, developing mitigation plans, diversifying transportation corridors and storage locations, providing alternate means of delivering fuels to end users, and coordinated planning (OSSPAC 2013).

The American Lifelines Association (ALA 2005) identified the high-level performance measures and performance metrics for pipeline systems shown in Table 7-1.

Table 7-1. The American Lifelines Association High-Level Performance Measures and Performance Metrics for Pipeline Systems (ALA 2005).

Desired Outcomes (Performance Targets)	System Performance Metrics					
	Capital Losses ($)	Revenue Losses ($)	Service Disruption (% service population)	Downtime (hours)	Casualties (deaths, injuries)	Lost Product
Protect public and utility personnel safety					X	X
Maintain system reliability			X	X		
Prevent monetary loss	X	X	X	X		X
Prevent environmental damage						X

A qualitative ranking of hazards to typical pipeline system components and facilities from the ALA (2005) study is reproduced in Table 7-2.

Table 7-2. Qualitative Ranking of Hazards to Typical Pipeline System Components and Facilities (ALA 2005).

Hazards	Degree of Vulnerability									
	Transmission Pipelines	Pump Stations	Compressor Stations	Processing Facilities	Storage Tanks	Control Systems	Maintenance Operations Buildings and Equipment	Pressure Regulations / Metering Stations	Distribution Pipelines	Service Lines or Connections
Natural Hazards										
Earthquake Shaking	L	M	M	M	H	M	H	L	L	M
Earthquake Permanent Ground Deformations (fault rupture, liquefaction, landslide and settlement)	H	-	-	-	L	-	-	L	H (Buried)	M
Ground Movements (landslide, frost heave, settlement)	H	-	-	-	L	-	-	L	H (Buried)	M
Flooding (riverine, storm surge, tsunami and seiche)	L	H	H	H	M	H	H	H	L	M
Wind (hurricane, tornado)	L (Aerial)	-	-	-	-	L	L	-	-	-
Icing	L	-	-	-	-	-	-	-	L	-
Collateral Hazard: Blast or Fire	M	H	H	H	H	M	L	L	L	M
Collateral Hazard: Dam Inundation	L	H	H	H	M	H	H	H	L	M
Collateral Hazard: Nearby Collapse	-	L	L	L	-	L	L	L	M	L
Human Threats										
Physical Attack (biological, chemical, radiological and blast)	M	M	M	M	-	M	M	-	M	-
Cyber Attack	-	L	L	L	-	H	L	-	L	-

Note: Degrees of vulnerability: H = High, M = Moderate, L = Low. When a component or system is located within a building the vulnerability of both the building and component should be considered. For example, where there is a potential for building collapse or mandatory evacuation, the equipment housed within is at risk. The entries in Table 4-2 assume that the component is of recent vintage, i.e., post 1945.

7.2.3. Natural Gas

Natural gas pipelines, port terminals, and storage facilities comprise a vast natural gas infrastructure that services 65 million homes, 5 million businesses, 193,000 factories and 5,500 electric generating facilities (McDonough 2013). Imports of Liquid Natural Gas are expected to rise by 700% by 2030 to meet increasing demand (ASCE 2013). There are nominally over 1,500,000 miles of natural gas pipelines in the continental US, with pipelines running along roads and private easements under both urban and rural lands (McDonough 2013). Steps need to be taken to safeguard this massive and ubiquitous part of our energy infrastructure from disastrous events.

Natural gas pipelines can be damaged via ground shaking, liquefaction, and ground rupture. Specific points of failure may be predicted when rupture or liquefaction occurs, but the most damaging event on a wide scale is ground shaking (Nadeau 2007). Existing weaknesses, which serve as the first points of failure, can include corrosion, bad welds, and weak or strained material. Regular maintenance can have a beneficial effect, as can upgrading piping from iron to plastic or even steel. Extensive work has been done to develop models that predict the impact of disasters on NG systems, which can help leaders determine the risk to their local facilities.

Generation, in addition to piping, needs to be resilient in the event of a disaster. Fuel cells, which generate power via electrochemical reaction rather than combustion, are already being used as a means to achieve a more resilient natural gas infrastructure. Fuel cells provide a decentralized, reliable source of power that has proven useful in disaster events. They are considered a distributed resource by IEEE. For example, during Hurricane Sandy, one manufacturer put 60 fuel cells in place to provide backup power to cell phone towers. Thanks to the inherent resilience of underground natural gas systems to non-seismic events, these cell towers remained operational during and after the storm. Notably, they were the only cell towers in the area to remain operational throughout the event (Fuel Cell and Hydrogen Energy Association 2014).

Port terminals, storage facilities, and generation plants are the most vulnerable parts of the natural gas system. Pipes are inherently protected from many disasters by being underground, but these buildings are subject to all the same risks as other commercial structures. In addition to the issues discussed in the section about structure resilience, there are vulnerabilities specific to natural gas facilities – flammability and high pressure hazards, and issues with the surrounding infrastructure. For example, a plant that has no roads for fuel trucks to import hydrogen is severely impaired (Fuel Cell and Hydrogen Energy Association 2014). These special vulnerabilities should be recognized and accounted for in addition to the steps taken to mitigate inherent risks of above-ground buildings.

7.2.4. Emergency and Standby Power

Loss of offsite power delivered by the commercial power grid can be triggered by failures in power generation, transmission, or distribution systems or by disruptions to power plant fuel supplies. The vulnerability of offsite power to nearly all hazards and the dependence of nearly all buildings and infrastructure on offsite commercial power combine to make both emergency and standby power key requirements for improving disaster resilience.

IEEE (1995) defines an emergency power system as “an independent reserve source of electric energy that, upon failure or outage of the normal source, automatically provides reliable electric power within a specified time to critical devices and equipment whose failure to operate satisfactorily would jeopardize the health and safety of personnel or result in damage to property.”

The National Electric Code (NFPA 2005) defines emergency systems as “those systems legally required and classed as emergency by municipal, state, federal, or other codes, or by any governmental agency having jurisdiction. These systems are intended to automatically supply illumination, power, or both, to designated areas and equipment in the event of failure of the normal supply or in the event of accident to elements of a system intended to supply, distribute, and control power and illumination essential for safety to human life."

A standby power system is defined by IEEE (1995) as "an independent reserve source of electric energy that, upon failure or outage of the normal source, provides electric power of acceptable quality so that the user's facilities may continue in satisfactory operation."

The NEC (NFPA 2005) divides standby power systems into two categories, as follows:

- ***"Legally Required Standby Systems:*** Those systems required and so classed as legally required standby by municipal, state, federal, and other codes or by any governmental agency having jurisdiction. These systems are intended to automatically supply power to selected load (other than those classed as emergency systems) in the event of failure of the normal source. Legally required standby systems are typically installed to serve loads, such as heating and refrigeration systems, communications systems, ventilation and smoke removal systems, sewage disposal, lighting systems, and industrial processes that, when stopped during any interruption of the normal electrical supply, could create hazards or hamper rescue and fire-fighting operations."
- ***"Optional Standby Systems:*** Those systems intended to supply power to public or private facilities or property where life safety does not depend on the performance of the system. Optional standby systems are intended to supply on-site generated power to selected loads either automatically or manually. Optional standby systems are typically installed to provide an alternate source of electric power for such facilities as industrial and commercial buildings, farms, and residences and to serve loads such as heating and refrigeration systems, data processing and communications systems, and industrial processes that, when stopped during any power outage, could cause discomfort, serious interruption of the process, damage to the product or process, and the like."

Emergency and standby power systems are essential for continuous operation of critical facilities, such as hospitals and emergency operations centers. Emergency and standby power are also needed to mitigate cascading failures of transportation and infrastructure systems that depend on electric power, including: communications networks, waste water lift stations, waste water treatment plants, water treatment plants, water distribution pumps, transportation fueling stations, traffic signals, traffic monitoring systems, and railway signals (ALA 2006).

Important considerations for safe and reliable operation of onsite emergency and standby power include:

- Elevation of all electrical components, including generators, service panels, outlets, etc., above a design flood level that is appropriate to the importance/criticality of the facility
- Proper ventilation of combustion products and cooling system components
- Availability of adequate uninterruptable power supply (UPS) to support critical systems until emergency or standby power comes on line
- Ability for to start emergency or standby power generation without power from the grid ("black start capability")
- Prioritization of power needs and proper sizing of generators and circuits to safely meet essential requirements
- Installation of permanent quick-connect hookups to accept power from temporary generators
- Ability to properly disconnect from the utility grid and to avoid feeding power back onto a de-energized grid ("islanding")
- Ability to safely transfer back to the grid when primary power is restored

National Fire Protection Association Standards 110 and 111 provide performance standards for *Emergency and Standby Power Systems* (NFPA 2013a) and *Stored Electrical Energy Emergency and Standby Power Systems* (NFPA 2013b). NPFA 110 recognizes two classification levels: critical to life and safety (Level 1) and less critical (Level 2). Level 1 applications include life safety illumination, fire detection and alarm systems, elevators, fire pumps, public safety communications systems, industrial processes where current interruption would produce serious life safety or health hazards, and essential ventilating and smoke removal systems. Level 2 applications include heating and refrigerating systems, other communications systems, other ventilating and smoke removal systems, sewage disposal, lighting, and industrial processes.

Key considerations for emergency and standby power system fuels include:

- Providing sufficient on-site fuel supply to support essential power loads until an ongoing supply of fuel can be safely and reliably delivered to the site
- Selecting a fuel that is not dependent on electricity from the grid for delivery (e.g., pipe-delivered, natural gas or truck-delivered liquid fuels such as diesel fuel)

Alternative fuel sources such as solar arrays with battery backups can be considered as a means of maintaining lighting for emergency exit paths or providing water pressure in buildings or for operating transportation system signals or pumps at fueling stations (Andrews et al. 2013).

A partial listing of technologies used for generating emergency or standby power includes:

- Diesel generators
- Combined Heat and Power (CHP)
- Microturbines
- Reciprocating gas engines
- Fuel cells

Diesel generators range from small mobile generators to larger permanently installed systems. Small generators can be easily deployed to power traffic signals, rail crossing signals, or critical circuits in residential or small commercial buildings; but they require frequent refueling, pose safety hazards to inexperienced operators, and may not be reliable due to poor maintenance and infrequent use. Theft of generators is also a problem when left unattended to power transportation system signals, for example. Permanently installed generators may have more substantial fuel capacities and may be safer to operate and more reliable if tested and maintained on a regular schedule.

Following Superstorm Sandy, the State of New Jersey used FEMA HMGP funds to establish a Retail Fuel Station Energy Resiliency Program (NJOEM 2014). Eligibility requirements for the program include:

- Stations must be located within ¼-mile of an identified evacuation route
- Stations with gasoline storage capacity of 30,000 to 35,000 gallons eligible for up to $15,000 grant to purchase quick-connect technology or to offset a portion of the cost of purchasing a generator
- Stations with gasoline storage capacity of more than 35,000 gallons eligible for up to $65,000 grant toward the purchase and installation of an onsite generator
- Stations must sell both gasoline and diesel fuel (except in limited instances)

The program requires a maintenance contract be in place for at least five years from the date of final approval of municipal building inspector. New Jersey’s Office of Homeland Security and Preparedness (OHSP) was also selected by the federal DHS to conduct the Regional Resiliency Assessment Program (RRAP) on the State’s petroleum transportation and distribution system.

Combined Heat and Power (CHP) is a highly efficient method of providing uninterrupted power and thermal (heating or cooling) services to a host facility. CHP systems are typically powered by natural gas fueled turbines or reciprocating engines. Over a dozen case studies of successful CHP system performance during Superstorm Sandy and other recent large scale power outages have been documented by Hampson et al. (2013). Key advantages of CHP systems over conventional diesel generators include better reliability, lower fuel costs, lower emissions, and the ability to address thermal demands in addition to power demands. Texas and Louisiana now require that all state and local government entities identify which government-owned buildings are critical in an emergency and that a feasibility study on CHP be conducted prior to constructing or extensively renovating a critical government facility. In New York, the State Energy Research and Development Authority (NYSERDA) and the State Office of Emergency Management have partnered to educate emergency managers about the benefits of CHP systems in emergency facilities; and the governor has announced a $20 million investment towards CHP projects, with added incentives for projects serving critical infrastructure, including facilities of refuge (Hampson et al. 2013).

7.3. Performance Goals

Examples of Performance Goals at the community level were presented in Chapter 3 for different elements of critical infrastructure. This section presents an example of performance goals for the Energy Sector. Previous work to develop and establish performance goals or levels of performance is found in the efforts undertaken by SPUR (San Francisco) and Oregon. While these efforts were first developed at the local and state levels, respectively, they represent the most recent examples of major urban centers and an entire state developing a resilience plan to improve hazard resistance and infrastructure performance.

Table 7-3 represents sample performance goals for the Electrical Subsector for the **Expected** event (The three event levels of Routine, Expected, and Extreme events were presented and discussed in Chapter 3 – the Expected event is generally synonymous with a “Design Level event” as defined by the relevant codes and standards.). Since the ability to provide services after a windstorm, ice storm, hurricane, or flood event allows a utility to win support from their customer base, many providers and entities in the Energy Sector have been designing and rebuilding their infrastructure to consider more severe events to make their systems more resilient and reliable for their customers. As such, we recognize that the 90% desired performance level is already at the existing or current performance level for most electric utilities in the sample matrix. However, the target performance levels proposed may not currently be what is being achieved by all utilities and providers. These performance goals are based on anticipated performance to support the communities in a manner that is considered resilient, based on recent actual events and response times after storm and hazard events the past several years, and anecdotal reporting of response times. Further, much of the current infrastructure and response efforts managed by larger utilities currently meet the 90% restored metric we have identified therefore we made that box blue as the “X” and 90% are “overlapping.” A notable caveat to this is that Municipals and Cooperatives (Muni’s and Co-Ops) are not performing at this level and across the board they would likely be at least one box to the right of the current condition (“X”) we mapped. That said, we do not feel they represent enough of the generation or transmission industry to push the box to the right so we did not move the X to the right at this time.

It is also important to note that, for this sector, there is a slight difference in the presentation of information related to percent of the Sector restored. The reality is that the percentage of the infrastructure the utilities look to get back on line immediately is not 30% of the infrastructure, but closer to 10% +/- for each sub element (such as Generation, Transmission, and Distribution). Therefore, the most critical clusters (or sub clusters) have a 10% restored metric included for discussion. Lastly, these performance goals will not capture or reflect the inability of the generation or transmission capabilities to be easily re-established when critical infrastructure assets are completely destroyed by an event (surge that completely destroys a generation station or major transmission substation). Major impact events such as these are generally considered in that the grid will have the ability to respond and absorb some level of infrastructure failure. However in communities where there is a generation, transmission, or substation single-point-of-failure condition that impact is not well-reflected in these metrics at this time.

Table 7-3. Sample Performance Goals for Power Systems within the Energy Sector

Disturbance		
(1)	Hazard	Any
	Hazard Level	Expected
	Affected Area	Community
	Disruption Level	Moderate

Restoration times		
(2)	10%	Restored
	30%	Restored
	60%	Restored
	90%	Restored
(3)	X	Current
	90%	At Goal

Functional Category: Cluster	(4) Support Needed	(5) Target Goal	Overall Recovery Time for Hazard and Level Listed								
			Phase 1 -- Response			Phase 2 -- Workforce			Phase 3 -- Community		
			Days 0	Days 1	Days 1-3	Wks 1-4	Wks 4-8	Wks 8-12	Mos 4	Mos 4-36	Mos 36+
Power - Electric Utilities											
Generation		1									
Critical Facilities and Infrastructure Systems	R/C		10%	30%	60%	90%					
Emergency Housing and Support Systems	R/C		10%	30%	60%	90%					
Housing and Neighborhood infrastructure	R/C					30%	60%	90%			
Community Recovery Infrastructure	R/C					30%	60%	90%			
Transmission (inculding Substations)		1									
Critical Response Facilities and Support Systems											
Hospitals, Police and Fire Stations			10%	30%	60%	90%					
Emergency Operations Centers			10%	30%	60%	90%					
Disaster debris/recycling centers			10%	30%	60%	90%					
Related lifeline systems			10%	30%	60%	90%					
Emergency Housing and Support Systems											
Public Shelters (General Population, Animal, etc.)					30%	60%	90%				
Food distribution centers					30%	60%	90%				
Nursing homes, transitional housing					30%	60%	90%				
Emergency shelter for response/recovery workforce				30%	60%	90%					
Related Lifeline Systems including recharging stations/banking facilities				30%	60%	90%					
Housing and Neighborhood infrastructure											
Essential city services facilities							30%	60%	90%		
Schools							30%	60%	90%		
Medical provider offices							30%	60%	90%		
Houses of worship/meditation/ exercise											
Buildings/space for social services (e.g., child services) and prosecution activities											
Food distribution from local grocery stores (location known by community)						30%	60%	90%	X		
Community Recovery Infrastructure											
Residential housing restoration							30%	60%	90%		
Commercial and industrial businesses							30%	60%	90%		
Non-emergency city services							30%	60%	90%		
Distribution											
Critical Response Facilities and Support Systems		1									
Hospitals, Police and Fire Stations				10%		30%	60%	90%			
Emergency Operations Centers				10%		30%	60%	90%			
Disaster debris/recycling centers				10%		30%	60%	90%			
Related lifeline systems				10%		30%	60%	90%			
Emergency Housing and Support Systems											
Public Shelters (General Population, Animal, etc.)							30%	60%	90%		
Residential Shelter-in-place							30%	60%	90%		
Food distribution centers							30%	60%	90%		
Nursing homes, transitional housing							30%	60%	90%		
Emergency shelter for response/recovery workforce							30%	60%	90%		
Related Lifeline Systems including recharging stations and banking facilities							30%	60%	90%		
Housing and Neighborhood infrastructure											
Essential city services facilities							30%	60%	90%		

Functional Category: Cluster	(4) Support Needed	(5) Target Goal	Overall Recovery Time for Hazard and Level Listed								
			Phase 1 -- Response			Phase 2 -- Workforce			Phase 3 -- Community		
			Days 0	Days 1	Days 1-3	Wks 1-4	Wks 4-8	Wks 8-12	Mos 4	Mos 4-36	Mos 36+
Schools							30%	60%	90%		
Medical provider offices							30%	60%	90%		
Houses of worship/meditation/ exercise							30%	60%	90%		
Buildings/space for social services (e.g., child services) and prosecution activities							30%	60%	90%		
Food distribution from local grocery stores (location known by community)						30%	60%	90%	X		
Community Recovery Infrastructure											
Residential housing restoration							30%	60%	90%		
Commercial and industrial businesses							30%	60%	90%		
Non-emergency city services							30%	60%	90%		
Related lifeline systems							30%	60%	90%		

Footnotes:

1 Specify hazard being considered
Specify level -- Routine, Expected, Extreme
Specify the size of the area affected - localized, community, regional
Specify severity of disruption - minor, moderate, severe

2 30% 60%

3 X Estimated restoration time for current conditions based on design standards and current inventory
Relates to each cluster or category and represents the level of restoration of service to that cluster or category
Listing for each category should represent the full range for the related clusters
Category recovery times will be shown on the Summary Matrix
"X" represents the recovery time anticipated to achieve a 90% recovery level for the current conditions

4 Indicate levels of support anticipated by plan
R Regional
S State
MS Multi-state
C Civil Corporate Citizenship

5 Indicate minimum performance category for all new construction.
See Section 3.2.6

7.4. Regulatory Environment

The Western Energy Crisis, the Enron scandal, and a historic East Coast blackout, led Congress to granted broad new authority to the Federal Energy Regulatory Commission (FERC) in 2005. After this third event, the Northeast Blackout, a joint US-Canada task force studied the causes and effects of the 2003 blackout and identified the need to make reliability standards mandatory and enforceable with penalties for noncompliance. So, in the Energy Policy Act of 2005 - Public Law 109-58 - (EPAct 2005), Congress entrusted FERC with a major new responsibility to oversee mandatory, enforceable reliability standards for the nation's Bulk Power System—that is, the wholesale power grid. The importance of this change cannot be overstated. The business of reliability became not just a set of industry best practices; it became a matter of national importance. Through Section 215 of the Federal Power Act, Congress authorized FERC to certify a national electric reliability organization. That ERO is the North American Electric Reliability Corporation (NERC).

NERC is a not-for-profit entity whose mission is to ensure the reliability of the Bulk Power System (BPS) in North America. This means that it is the responsibility of NERC to develop and enforce Reliability Standards. Further, they are to annually assess seasonal and long-term reliability, monitor the BPS through system awareness, and educate, train, and certify industry personnel.

7.4.1. Federal Codes and Regulations

At the federal level there is regulation by FERC who in short defines its role as "an independent agency that regulates the interstate transmission of electricity, natural gas, and oil. FERC also reviews proposals to build liquefied natural gas (LNG) terminals and interstate natural gas pipelines as well as licensing hydropower projects."

NERC is also at the federal level which, as defined, is “a not-for-profit international regulatory authority whose mission is to ensure the reliability of the bulk power system in North America. NERC develops and enforces Reliability Standards; annually assesses seasonal and long-term reliability; monitors the bulk power system through system awareness; and educates, trains, and certifies industry personnel. NERC’s area of responsibility spans the continental United States, Canada, and the northern portion of Baja California, Mexico. NERC is the electric reliability organization for North America, subject to oversight by the Federal Energy Regulatory Commission and governmental authorities in Canada.”

Each of the various state and federal authorities regulates different and overlapping aspects of the electric system. The requirements, standards and codes for each are lengthy and complex and are ever evolving but it is these that must form the basis for future refinements to facilitate reliability and preparedness improvements.

7.4.2. State Codes and Regulations

The utilities are constantly in a complex regulatory dance with the state public service commissions regarding the rapidly changing rules governing their role and responsibilities. Recently one of the biggest issues for utilities and commercial generators, particularly rooftop solar companies, involves the regulation of “behind the meter” load (such as rooftop solar) and their ability to sell power back into the grid to the utility. This is referred to as “net metering” and, again, the rules vary from state to state; but the concern from utilities is that they remain responsible for the upgrade and maintenance of a grid interconnection system that would receive less revenue and would also need to handle the varying bi-directional load demands that can add complexity to an already stressed infrastructure.

Although the push to lower greenhouse gas emissions and increase self-reliance using on-site methods such as roof-top solar (and potentially storage) has merit, so too does improving the backbone and efficiency of our electric grid. Grid improvements can also dramatically reduce line loss, thereby increasing environmental benefits and reliability but those improvements are expensive and require significant investment. The debate is escalating as additional unique and beneficial “generation” and “virtual generation” options arise.

This push-pull is being played out right now in the headlines and before state public service commissions (PSCs) and utilities across the country. It is therefore imperative that these evolving rules of conduct be formulated with an eye to cost, reliability, safety, disaster preparedness and environmental benefit. The rules themselves will be primarily administered by state PSCs and the utilities but the oversight roles of the regional Independent System Operators (ISOs) and the regional transmission organizations (RTOs) is also key, particularly with respect to cost and reliability.

The ISOs and RTOs serve much the same function, though the RTOs have greater responsibility for their regional transmission network as established by FERC. However, both the ISOs and RTOs operate regional electricity grids, administer the wholesale electricity markets, and provide reliability planning for the bulk electric system. Some of these systems such as the New York ISO (NYISO) are single state systems, and some are more regional such as the ISO New England (ISO-NE) system and the Southwest Power Pool (SPP). Due to the inter-relatedness of the North American grid, the ISO/RTO systems are international and include for example, the Alberta Electric System Operator.

7.4.3. Local Codes and Regulations

At the State and Local levels, codes and standards are adopted by the State PSCs, PUCs, ISOs, and RTOs to govern design and construction of the infrastructure. There is a wide variation in the level of design guidance that is provided by the codes and standards adopted by these entities. While some have best-practices, others reference ANSI-approved, consensus codes and standards. But even when the codes and standards are adopted, there is an apparent lag in adopting the most current version of these standards.

7.5. Codes and Standards

A number of codes and standards are used in the power industry for design and construction of generation, transmission, stations/substations, and distribution assets. While ASCE 7 (mentioned earlier in this document) is now incorporated by reference and used more frequently than in the past, most of the Transmission and Distribution assets are designed to the National Electric Safety Code (NESC) or the Rural Utilities Service (RUS), respectively. There are many variables related to design and construction of these assets. As such, not all elements may be addressed here or will require additional cross checking with additional codes, standards, and regulations.

The electric codes that are adhered to by the Investor-Owned Utilities (IOUs) who design and construct the Transmission assets is the National Electric Safety Code (NESC); Sections 24 (Grades of Construction), 25 (Loading Requirements) and 26 (Strength Requirements). While this is truly a safety code, it is applied for use as a design code in lieu of other guidance. Each utility also has a Standards department that evaluates the various codes and standards (safety or design) that are applied during design and construction of their assets. They evaluate any new equipment to ensure it meets or exceeds these standards. From the baseline set forth in the NESC, it is important to note that all IOUs have developed their own standards for their respective systems. And while most all exceed the minimums set forth by the NESC, the question that exists is whether the baseline set forth in the NESC addresses the performance desired for resiliency when considering all hazards (flood, wind, seismic, ice, and other natural hazards and man-made threats).

In a similar fashion, but working from a different set of criteria, the Co-operatives and Municipalities responsible for Distribution assets use the design manuals/standards from the Rural Utilities Service (RUS). The RUS distribution line design manuals consist of RUS bulletins 1724-150 through 1724-154. These refer to the identification of critical loads/customers and poles/equipment. In all cases, each utility is applying more constringent wind and ice loading conditions from these codes.

7.5.1. New Construction

[Note to reviewers: This section is still under development and will be refined for a future draft.]

For some elements of the Energy Sector, the design criteria for hazards have been aligned with Building Sector standards such as ASCE 7 Minimum Design Loads for Buildings and Other Structures. However, performance goals for these systems for each event are less defined. Definitions are also less clear regarding what are considered "major," "rare," "extreme," or "catastrophic" events. As resilience becomes better defined, this framework is working to bring together different interpretations and definition of these events as they are defined and used in practice within the existing industries and codes / standards used in each industry.

7.5.1.1. Implied or stated Performance Levels for expected hazard levels

Summary of Hazards Considered by the NESC (Part 2, Section 25):

- ***250B – Combined Ice and Wind –*** This is the basic loading criteria and is known as the District Loading. It incorporates both wind and ice with overload and strength factors. This applies to all structures and references the map presented in Figure 250-1. The boundaries of the districts follow county lines. Data was obtained from a small number of weather stations which were far apart. While the industry has discussed replacing this map with appropriate maps from ASCE 7, this issue is still being evaluated.
- ***250C – Extreme Wind –*** These criteria account for the higher winds typically found along the coastline and during extreme events. These criteria are only used for structures that are higher than 60' above ground (70' pole and longer). Appropriate maps are Figures 250-2a through 250-2e. Due to their typical tower height, transmission lines are designed to these criteria. The overload and strength factors used are generally 1 since this is an extreme event map (note, the nomenclature of "extreme

wind" used here is not consistent with the extreme wind event used for the design and construction of buildings or storm shelters per the ICC-500 *Standard for the Design and Construction of Storm Shelters*). These criteria were first introduced into the NESC in 1977. The 2002 NESC incorporated the wind maps from ASCE 7-98; where the wind data was much more comprehensive. The 2012 NESC uses the wind maps from ASCE 7-05. The ASCE 7-10 wind maps were revised to better represent the wind hazard. The maps now are based on new modeling efforts, refinements to understanding of wind performance, and incorporation of the contribution of the Importance Factor [I] into the data presented by the maps. However, these maps are currently not used by the NESC based on a decision by their code committee to retain the use of the ASCE 7-05 wind maps.

Most distribution structures are lower than the 60 ft height limitation, therefore, most utilities will not design their distribution lines to the ASCE 7 criteria (something that may want to be reconsidered depending upon performance of these systems during hurricanes and tornadoes over the past 2 decades).

- ***250D – Combined Ice and Wind –*** This criterion was added in the 2007 NESC to account for extreme ice events. This criterion is similar to the Extreme Wind loading. Most Transmission assets will be designed to this criterion while distribution assets will not. Over the years most utilities had their own extreme ice loading for the design of Transmission assets. The maps from ASCE 7-05 have been retained and referenced for this criterion.
- Additional Standards related to hazard-resistant design include:
  - ASCE 7-10 exempts electrical lines from seismic design
  - ASCE 113 applies design criteria for stations. Seismic design is addressed in this standard.
  - ANSI O5 applies to wood poles.
  - ANSI C29 applies to insulators.

Some utilities on the East coast are now starting to look at station hardening due to hurricane Sandy. This includes raising structures and control buildings at existing stations, or relocating the station outside the flood zone. Much of this guidance is a result of state and local floodplain management practices and requirements as opposed to specific codes, standards, or regulations from the energy sector itself.

7.5.1.2. Recovery levels

This section is under development. Text to be included in a future draft.

7.5.2. Existing Conditions

This section is under development. Text to be included in a future draft.

7.5.2.1. Implied or stated Performance Levels for expected hazard levels

This section is under development. Text to be included in a future draft.

7.5.2.2. Recovery levels

This section is under development. Text to be included in a future draft.

7.6. Resilience Assessment Methodology

Because resilience is new, there is a huge need for tools to help both the community and the sector assess resilience. There are tools and methods to measure reliability, but again, these calculated values typically look at systems during "blue sky" events and not during severe or extreme events.

Thinking about resilience as an aspect of reliability might be the quickest means to develop assessment methodologies to assess and score resilience. It may allow the ability to explicitly consider large-scale events and non-traditional hazards that were sometimes neglected in previous assessments. It would also set up a means to consider resilience in the current sector mode that allows for variable pricing for duration and a better understanding of scale by adapting to risk-based frameworks that capture interdependencies and likelihood. By assimilating resilience into the factors that assure reliability, regulators might not be charged with setting new criteria for utility performance.

7.6.1. Assessment Methodology (current conditions, including dependence on sources outside the community)

The length of time needed to restore electric service is a traditional metric of grid reliability. Similarly, the grid's ability to ride through minor disturbances or avoid cascading outages is already considered within existing grid reliability indices. While these metric and indices (such as System Average Interruption Duration Index [SAIDI], the Customer Average Interruption Duration Index [CAIDI], the System Average Interruption Frequency Index [SAIFI], the Customer Average Interruption Frequency Index [CAIFI], and others) exist, there are limitations to how these apply to the grid, including the fact that most reliability indices and metrics are "blue-sky" indicators. When looking at and defining resilience, the events that cause us to measure and evaluate the performance of the grid take place in much harsher and significant conditions (such as natural hazard events and act of vandalism, crime, and terrorism).

7.6.2. Strategies for new/future Construction

This section is under development. Text to be included in a future draft.

7.6.3. Strategies for Existing Construction

This section is under development. Text to be included in a future draft.

7.6.4. Addressing Gaps in Resilience Plans

This section is under development. Text to be included in a future draft.

7.7. Tools Needed for Resilience

This section is under development. Text to be included in a future draft.

7.7.1. Standards and Codes

This section is under development. Text to be included in a future draft.

7.7.2. Practice and Research Needs

This section is under development. Text to be included in a future draft.

7.8. Summary and Recommendations

Many electric systems across the nation are currently being upgraded to accommodate the rapid load growth and aging infrastructure. With the upgrade there is a major focus on building resiliency in the system; however, the criteria detailing that resiliency and its consistency across all system owners is not present. As the various utilities across the nation balance the required investment with design criteria and the overall impact to customers there will be a more resilient system than what exists today. Technology is rapidly expanding, which allows a quicker response time to any potential disaster. In some cases utilities are reaching the point where they can predict an impact to the system and begin to minimize the impact prior to the event.

More can be done. In addition to reliability initiatives, improved planning, and response efforts to natural hazard and human-caused (criminal or terrorist) events, a planned and coordinated evaluation of the approaches to harden the infrastructure itself is necessary.

- Regulatory bodies for design and construction from the building sector and the energy sector need to discuss the magnitude and criteria of the hazards the buildings and infrastructure are designed to resist. If the general building stock is designed to resist higher level events with minimal damage, there will be greater pressure on the energy infrastructure to be on-line immediately after disasters and events occur.

- The baseline design criteria in the NESC and RUS should be increased to provide consistent and unified guidance to all entities designing above these minimums. This increase will ensure all hazards are addressed for the same return period of event.
- Study and determine what design strategies (i.e. using more switching within the Distribution Networks) can have a major impact on isolating damaged or impacted segments of the grid and provide opportunities to return to full service more quickly and easily.
- Study system criticality data that is documented in the NERC Brightline Assessments to highlight and prioritize the critical assets of the systems that should be mitigated first to improve resiliency.
- Identify and provide incentives for the energy sector entities to invest in their aging infrastructure prior to storm events.

7.9. References

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