7. Energy Sector

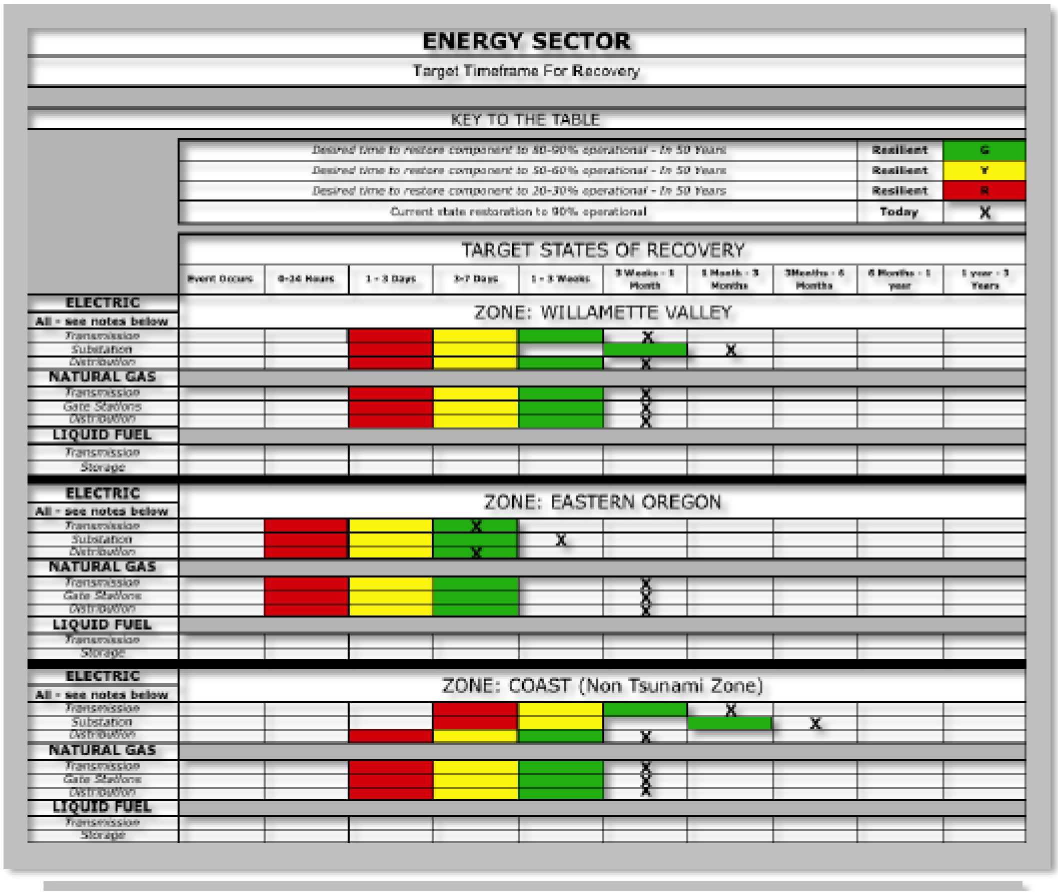
7.1. Introduction

The aging infrastructure throughout the United States is a major issue for all of the communities nationwide. Although progress has been made in upgrading of the existing electric infrastructure, to a smart grid – grid modernization is projected to continue for the next 25 years. The demand for electricity has increased by over 25% since 1990 which is causing an additional need to upgrade the physical plant and build for resiliency. In an effort to build a resilient energy infrastructure there needs to be an understanding of the desired level of resilience and the anticipated cost to accomplish this effort.

As communities address these issues with the utilities there will be a focus across the nation to understand the needs of the consumer (public safety, hospitals, businesses, and residences). The systems need to have the ability to adapt to the ever changing environment and be built so that we can 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 give the various utilities, Municipalities and Co-operatives across the country the ability to maintain the system while keeping the costs down. Given that some of these utilities are living in a competitive environment it will be necessary for them to find the least cost alternative while not impacting the resiliency of the overall complex network. But there may be a need for consumer education as approaches to facility and infrastructure hardening may not be in balance with the expectation of performance. If major changes are needed to address the expectation of readily available energy, fuels, and power after events (from minor, to major, and even after catastrophic events) new partners in the community must be brought to the table.

7.2. Performance Goals

As an example of the levels of performance SPUR (San Francisco) and Oregon took similar approaches in most places, of course with very different communities in mind – but are the most recent examples of major urban centers and an entire state developing a resilience plan to improve hazard resistance and infrastructure performance. The following example table is from the Oregon Resilience Plan. [Note to reviewers, we support the idea of using shaded regions for "where we want to be" and an X or checkmark for communities to use when they evaluate where they are. It helps define the gaps really well from a visual perspective. We could use more tables like this in the "Resilience Gaps" section with examples. (i.e., in this section, no X's; in the Gaps section, example X's)]. This is not to say these Energy Sector is more vulnerable, rather, the minimum baseline that has been set is lower. Since the ability to provide services after a windstorm, ice storm, hurricane, or flood event can provide a utility the ability to win support from their customer base, many of 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. 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*. What is less defined is the performance goals for these systems for each event and also what are consider "major", "rare", "extreme", or "catastrophic" events. As resilience is becoming 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. [Note to reviewers, we are working to prepare a table similar to the SPUR table with a more national view. The intent of the table is to provide the industry a common platform to identify and define the performance goals that exist currently and that will be vetted out to be become the desired performance goals for this Framework.]



ENERGY SECTOR		
Target Timeframe For Recovery		
KEY TO THE TABLE		
Desired time to restore component to 80-90% operational - In 50 Years	Resilient	G
Desired time to restore component to 50-60% operational - In 50 Years	Resilient	Y
Desired time to restore component to 20-30% operational - In 50 Years	Resilient	R
Current state restoration to 90% operational	Today	X

TARGET STATES OF RECOVERY	Event Occurs	0-24 Hours	1 - 3 Days	3-7 Days	1 - 3 Weeks	3 Weeks - 1 Month	1 Month - 3 Months	3Months - 6 Months	6 Months - 1 year	1 year - 3 Years
ZONE: WILLAMETTE VALLEY										
ELECTRIC										
All - see notes below										
Transmission						X				
Substation							X			
Distribution						X				
NATURAL GAS										
Transmission						X				
Gate Stations						X				
Distribution						X				
LIQUID FUEL										
Transmission										
Storage										
ZONE: EASTERN OREGON										
ELECTRIC										
All - see notes below										
Transmission				X						
Substation					X					
Distribution				X						
NATURAL GAS										
Transmission						X				
Gate Stations						X				
Distribution						X				
LIQUID FUEL										
Transmission										
Storage										
ZONE: COAST (Non Tsunami Zone)										
ELECTRIC										
All - see notes below										
Transmission							X			
Substation								X		
Distribution						X				
NATURAL GAS										
Transmission						X				
Gate Stations						X				
Distribution						X				
LIQUID FUEL										
Transmission										
Storage										

7.3. 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 have been 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 that 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 but may have also inadvertently introduced new vulnerabilities or risks into the system. Recent post disaster studies and reports on climate change have shed some light on why have we seen the damage and impacts to these systems from the natural hazard events that have occurred of the past several years. But now we need 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 why the failures occurred. Were the design criteria not correct to account for these storms? Can and should higher criteria be used? Or were these recent storms truly rare or extreme events that are not feasible to design the systems to resist with minimal to no impact to the services they provide when these particular events occur?

7.3.1. Electric Power

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

7.3.1.1. Generation

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

7.3.1.2. Transmission

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

In an industry that started with rapid innovation and expansion, it has become one that typically resisted change and has changed very little over last 75 years, 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 have also increased significantly over the years due to public routing, regulatory and environmental restrictions.

All of these demands will have an impact on the reliability of the electric transmission system. There is ever increasing cyber based monitoring systems that are being developed to reduce the impact of any potential natural disaster such as the hurricanes and flooding over the last several years. As the intensity of storms are predicted to increase, so does the structural requirements of the transmission assets.

As new systems are being engineered and constructed there is also a need to evaluate the on-going maintenance that currently is taking place. As with any engineered infrastructure, there is a design life span for every transmission line and there are an ever increasing number of older lines that need regular condition assessments to maximize the utilization of each asset. 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. There are several major Smart Grid transmission projects that 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 such as Demand Response, Micro-grid/Islanding, Synchrophasers (PMU), Dynamic Transfer, Energy Imbalance Markets (EIM) and Dynamic Line Rating (DLR). The FERC has also issued Order 1000, meant to help reduce the capital costs of transmission for the end consumers by introducing competition between utilities and transmission developers

7.3.1.3. Distribution

Given the aging infrastructure there are some real vulnerabilities in the Distribution systems of the Energy Sector. The Distribution systems are typically built and constructed along the roadside but in some cases they run through back lots and other right-of-ways which are not as easily accessible. As the overall customer load requirements continue to grow, and the changes in the various regulations continue to change, 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 make up 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 the 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 being engineered and constructed there is a need to evaluate the on-going maintenance that currently is taking place. One element of maintenance that is in the forefront is along the Distribution system in the locations there is substantial tree coverage. It is notable that, most if not all utility entities have well established and adequate tree management programs. But the lack of implementation of these robust tree trimming programs has been a leading cause of many outages. The reason for this is not always simple. Many of the land owners will not allow for the removal of any trees or limbs. Other jurisdictions and environmental entities (state, local, or activist) have also been successful in stopping tree trimming and clear programs. The aggregate impact of all these actions results in the failed implementation of the tree trimming programs, which creates a critical failure point where the vulnerability of these systems continues to worsen instead of being mitigated.

There is ever increasing cyber based monitoring systems that are being developed annually to reduce the impact of any potential natural disaster such as the hurricanes and flooding over the last several years. As the intensity of the storm is predicted to increase, so do the structural requirements of the transmission assets.

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, the wood poles they are increasing the size and class to accommodate the overall design constraints.

7.3.1.4. Emerging Technologies

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

7.3.2. 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 the following:

1. Catastrophic loss of major production fields
    a. Fires

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

Maintaining the 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.

U.S. refineries (Step 3) tend to be geographically concentrated and are utilized at 90% or more of capacity during periods of strong economic growth (USEIA 2014b). The reliability and resiliency of U.S. refinery capacity is both a national security issue and a major regional economic issue in those areas of the U.S. 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 back-up 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 following high-level performance measures and performance metrics for pipeline systems:

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**

Source: American Lifelines Association (ALA 2005)

A qualitative ranking of hazards to typical pipeline system components and facilities from the ALA (2005) study is reproduced below:

Hazards	Degree of Vulnerability									
	Transmission Pipelines	Pump Stations	Compressor Stations	Processing Facilities	Storage Tanks	Control Systems	Maintenance and Operations Buildings and Equipment	Pressure Regulating/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, and 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.

Source: American Lifelines Association (ALA 2005)

7.3.3. 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), and imports of Liquid Natural Gas are expected to rise by 700% by 2030 in order to meet increasing demand (ASCE 2013). There are nominally over 1,500,000 miles of natural gas pipelines in the continental U.S., with pipelines running along roads and private easements under both urban and rural lands (McDonough 2013). Steps need to be taken in order 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 will serve as the first points of failure and 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 can predict the impact of disasters on NG systems, which can help leaders get an idea of 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 allow for 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 had 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 of 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. Weaknesses that are specific to natural gas terminals and plants include flammability hazards, 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 need to be recognized and accounted for in addition to the steps taken to mitigate inherent risks of above-ground buildings.

7.3.4. 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 dependency of nearly all buildings and lifelines 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 lifeline 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 utilized for generating emergency or standby power includes the following:

- 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 can also be 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 be 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 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 together 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).

7.4. Regulatory Environment

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

7.4.1. Federal (FERC)

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

7.4.2. State

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

7.4.3. Local

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

7.5. Standards and Codes

There are a number of codes and standards that are used in the power industry for the design and construction of generation, transmission, stations/substations, and distribution assets. While ASCE 7 (mentioned earlier in this document) is now incorporate by reference and use than in the past, much of the design of the Transmission and Distribution assets are design to the National Electric Safety Code (NESC) or the Rural Utilities Service (RUS), respectively. There are many variables related to the 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 all of the various codes and standards (safety or design) that are applied during the design and construction of their assets. They evaluate any new equipment to make sure 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 if 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 the 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.

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 – This criteria accounts for the higher winds typically found along the coastline and during extreme events. This criteria is 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 this 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*). This criteria was first introduced into the NESC in 1977. The 2002 NESC incorporated the wind maps from ASCE 7-98; where the 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 criteria was added in the 2007 NESC to account for extreme ice events. This criteria is similar to the Extreme Wind loading. Most Transmission assets will be designed to this criteria 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 criteria.

- 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 that is now being used 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. New Construction

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

7.5.1.1. Performance Levels

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

7.5.1.2. Hazard Levels

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

7.5.1.3. Recovery Levels

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

7.5.2. Existing Construction

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

7.5.2.1. Performance Levels

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

7.5.2.2. Hazard Levels

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

7.5.2.3. Recovery Levels

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

7.6. Reliability vs. Resilience

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

[Note to reviewers, for a future draft of the document the authors intend on providing a discussion and a table to help show how Reliability and Resilience relate to one another. In many cases, the projects and investments being made improve day-to-day reliability contribute to Resilience however, there is not a one-to-one comparison. We feel that to provide a more resilient energy sector more investment will need to be made and we hope to use to table to highlight the areas that might need that investment.]

7.7. Resilience Needs

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

7.7.1. Standards and Codes

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

7.7.2. Practice and Research Needs

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

7.8. Summary and Recommendations

Many of the 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 the design criteria and the overall impact to the customers there will be a more resilient system then what exists today. Technology is rapidly expanding which is allowing a quicker response time to any potential disaster. In some cases Utilities are getting to the point where they can predict an impact to the system and begin to minimize the impact prior to the event.

But more can be done. Alongside the reliability initiatives, improved planning, and response efforts in response to natural hazard and human-causes (criminal or terrorist) events, is a planned and coordinated evaluation of the approaches to harden the infrastructure itself.

- 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 being designed to resist. If the general building stock is being 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 so as to provide consistent and unified guidance to all the entities designing above these minimums. This will ensure all hazards, not just some of them, are being 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 the 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.

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