Sector Resilience Report: Electric Power Delivery

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SCOPE

The Department of Homeland Security Office of Cyber and Infrastructure Analysis (DHS/OCIA)[1] Homeland Infrastructure Threat and Risk Analysis Center (HITRAC) produces Sector Resilience Reports to improve partner understanding of the interdependencies and resilience of certain sectors. Specifically, this report provides a brief overview of the electric power system, and analysis of key electric power system dependencies and interdependencies. Additionally, this product includes an assessment of, and best practices for, improving community, system, and facility resilience. This Sector Resilience Report was produced to complement other sector-specific guidance, analysis, and scholarly papers on infrastructure resilience by applying data obtained from DHS site visits and assessments analyzing the resilience of critical infrastructure assets and systems.

The resilience issues and best practices identified in this document may be considered by critical infrastructure partners in each sector to improve their resilience at three levels: electric power provider systems and facilities, community risk management organizations (e.g. State or local emergency operations centers or fusion centers), and any critical infrastructure asset or system that depends on electric power. This product was coordinated with the DHS Office of Infrastructure Protection, the Department of Energy (DOE), and the Federal Energy Regulatory Commission (FERC).

KEY FINDINGS

- **Of the 3,352 sites across all 16 sectors that received DHS assessments (2009–2012), 90 percent depend on electric power for core operations.**
- **Critical dependencies and interdependencies of the Energy Sector mean that the loss of electric power can quickly cascade to other lifeline infrastructure systems (including Water, Wastewater, Communications, Transportation, and Information Technology (IT)), potentially degrading services necessary for public health and safety.**

[1] In February 2014, NPPD created the Office of Cyber and Infrastructure Analysis by integrating analytic resources from across NPPD including the Homeland Infrastructure Threat and Risk Analysis Center (HITRAC) and the National Infrastructure Simulation and Analysis Center (NISAC).

- **Of the 41 electric power substations assessed by DHS, 59 percent depend upon an external source of electric power for on-site operations, 62 percent depend on communications, and 77 percent depend on IT to maintain operations.**
- **Interruption to IT supporting infrastructures, including the loss of electric power, could limit the operating flexibility and efficiency of electric substations and system monitoring equipment. A large-scale IT disruption could potentially impact power delivery to other critical infrastructure assets in the electric service area.**

ELECTRIC POWER DELIVERY SYSTEMS OVERVIEW

The U.S. electric power delivery system is a highly complex network of substations and electric lines that transport electricity from generators to residential, commercial, and industrial consumers. For this reportthe electric power delivery system includes all components between the point where power is injected into the grid and the point where the power enters the customer's premises. Figure 1 provides an overview of a representative electric power delivery system, and identifies nodes along the electric system that are suseptible to certain key hazards.

The contiguous 48 States, most of Canada, and parts of Mexico are served by a bulk power system comprising more than 200,000 miles of high-voltage transmission lines (230 kilovolts (kV) or greater), tens of thousands of miles of distribution lines operated at lower voltages, and an estimated 100,000 substations from which power is ultimately directed to customers.[2,3,4,5] To facilitate efficient transfer over long distances, electricity produced at a power plant is first directed to step-up transformers located in transmission substations, where the voltage is increased and then introduced into the transmission grid.

When the power arrives near a distribution territory, step-down transformers located in distribution substations reduce the voltage and transfer the power to the distribution grid along smaller distribution lines that are buried or carried on poles. Transformers located closer to individual customers, often on poles, further reduce the voltage to meet each customer's demand. Substations at both the transmission and distribution levels are strategically interconnected, giving operators multiple pathways by which to deliver power to meet individual loads and greatly enhancing the overall resilience of the electrical transmission and distribution networks.

[2] DHS and U.S. Department of Energy (DOE), *Energy Sector-Specific Plan*, 2010, accessed May 9, 2013, www.dhs.gov/xlibrary/assets/nipp-ssp-energy-2010.pdf.
[3] Edison Electric Institute. "Electricity Transmission," 2013, accessed January 29, 2013, www.eei.org/ourissues/ElectricityTransmission/Pages/default.aspx.
[4] Argonne National Laboratory, *Assessment of the Potential Costs and Energy Impacts of Spill Prevention, Control, and Countermeasure Requirements for Electric Utility Substations*, 2006, accessed January 29, 2013, www.fossil.energy.gov/programs/oilgas/publications/environment_otherpubs/SPCC_Impact_Substations_May_2006.pdf.
[5] DHS/OCIA (formerly HITRAC), *Infrastructure System Overview: The Bulk Power System*, September 23, 2013.

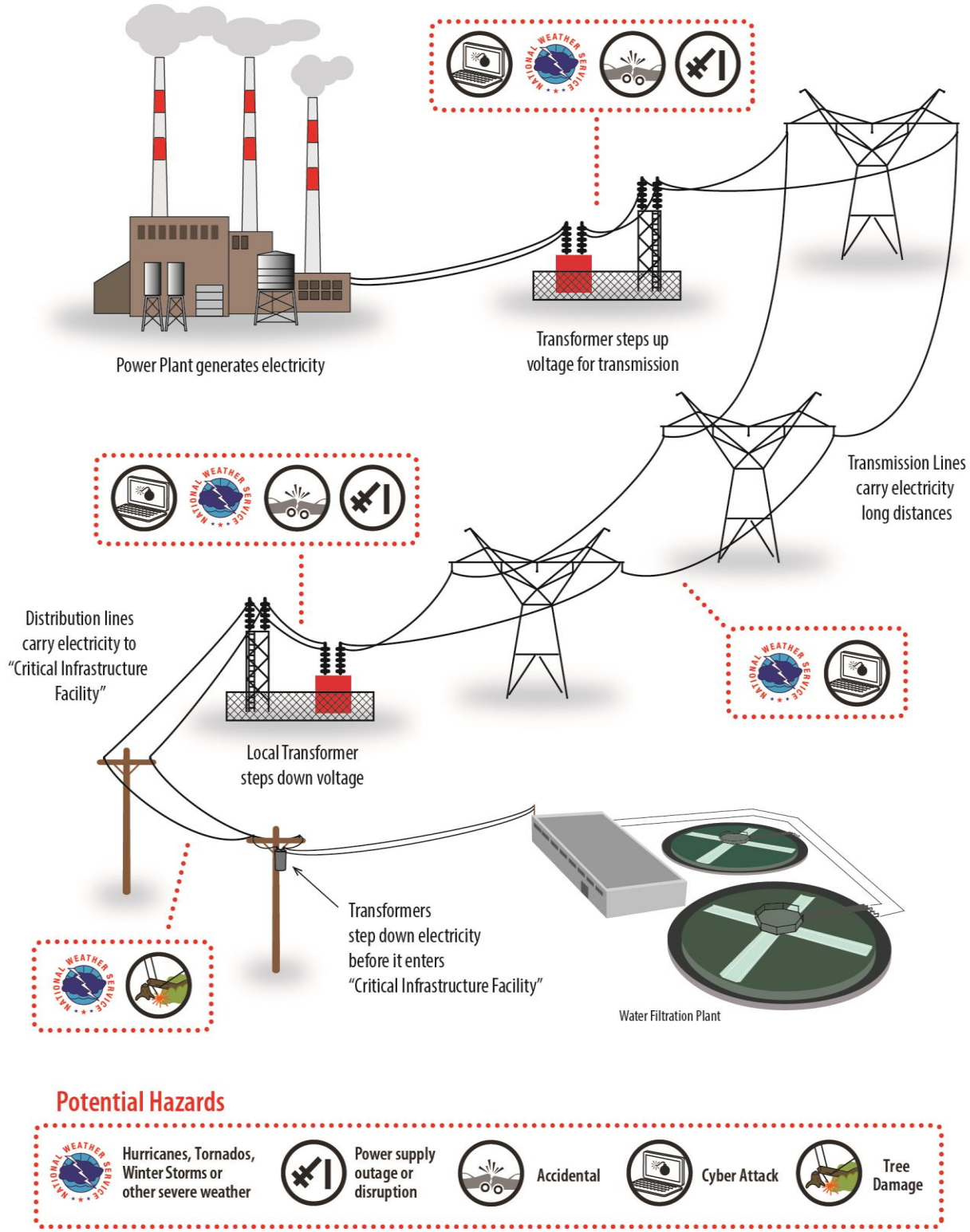

FIGURE 1.—Electric Grid Overview and Vulnerabilities to Potential Hazards (Courtesy of DHS and Argonne National Laboratory).

RESILIENCE

The common themes shared in this report are drawn from data obtained from DHS site visits, including the Enhanced Critical Infrastructure Protection (ECIP) Initiative, analysis produced by the Regional Resiliency Assessment Program (RRAP), and information gleaned from industry reports and academic research.[6,7] This paper summarizes results from numerous infrastructure assessments that examine vulnerabilities, threats, and potential consequences from an all-hazards perspective, leading to the identification of dependencies, interdependencies, cascading effects, and resilience characteristics.[8]

PPD—8, National Preparedness, defines resilience as "the ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies."

PPD—21, Critical Infrastructure Security and Resilience, directed the Federal Government to work with critical infrastructure owners and operators and State, local, tribal, and territorial partners to strengthen the security and resilience of its critical infrastructure.

Since 1996, the critical infrastructure community has evolved from a primary focus on protective security to a greater emphasis on resilience to disruptive events.[9] National policies, such as Policy Presidential Directives (PPDs) 8 and 21, highlight that collaborative engagement and information sharing with Federal agencies, private sector facility owners and operators, law enforcement, emergency response organizations, academic institutions, and other stakeholders are vital to building a more resilient Nation.

THREATS AND HAZARDS

The electric power delivery system faces a broad range of potential threats and hazards, ranging from cyberattacks to a variety of natural hazards, including various weather-related phenomena (as shown in Figure 1). Electricity infrastructure is highly automated and controlled by utilities and regional grid operators that rely on sophisticated industrial control systems. These control systems may be vulnerable to cyberattacks that could potentially disrupt electric power production or transmission. Accidents or physical attacks on electric power infrastructure, such as targeted shooting of transformers or intentional downing of power lines, also pose a threat for the Sector's continued reliable operations.[10] Natural events such as hurricanes, earthquakes, winter storms, wildfires, and solar flares also present a significant hazard to the electric power system, as these events occur regularly and have the capacity to cause extensive and widespread

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[6] The RRAP evaluates critical infrastructure on a regional level to examine vulnerabilities, threats, and potential consequences from an all-hazards perspective, identifying dependencies, interdependencies, cascading effects, resilience characteristics, and gaps. RRAP projects are voluntary and non-regulatory, and rely on engagement and information sharing with Federal agencies, private sector facility owners and operators, law enforcement, emergency response organizations, academic institutions, and other stakeholders. For more information, please email resilience@dhs.gov or visit www.dhs.gov/regional-resiliency-assessment-program.

[7] The ECIP Initiative is a voluntary program where DHS Protective Security Advisors conduct outreach with critical infrastructure facility owners and operators and provide security surveys, training and education, and recommended protective measures. ECIP metrics provide DHS with information on the protective and resilience measures in place at facilities and enable detailed analyses of site and sector vulnerabilities. For more information, please contact PSCDOperations@hq.dhs.gov.

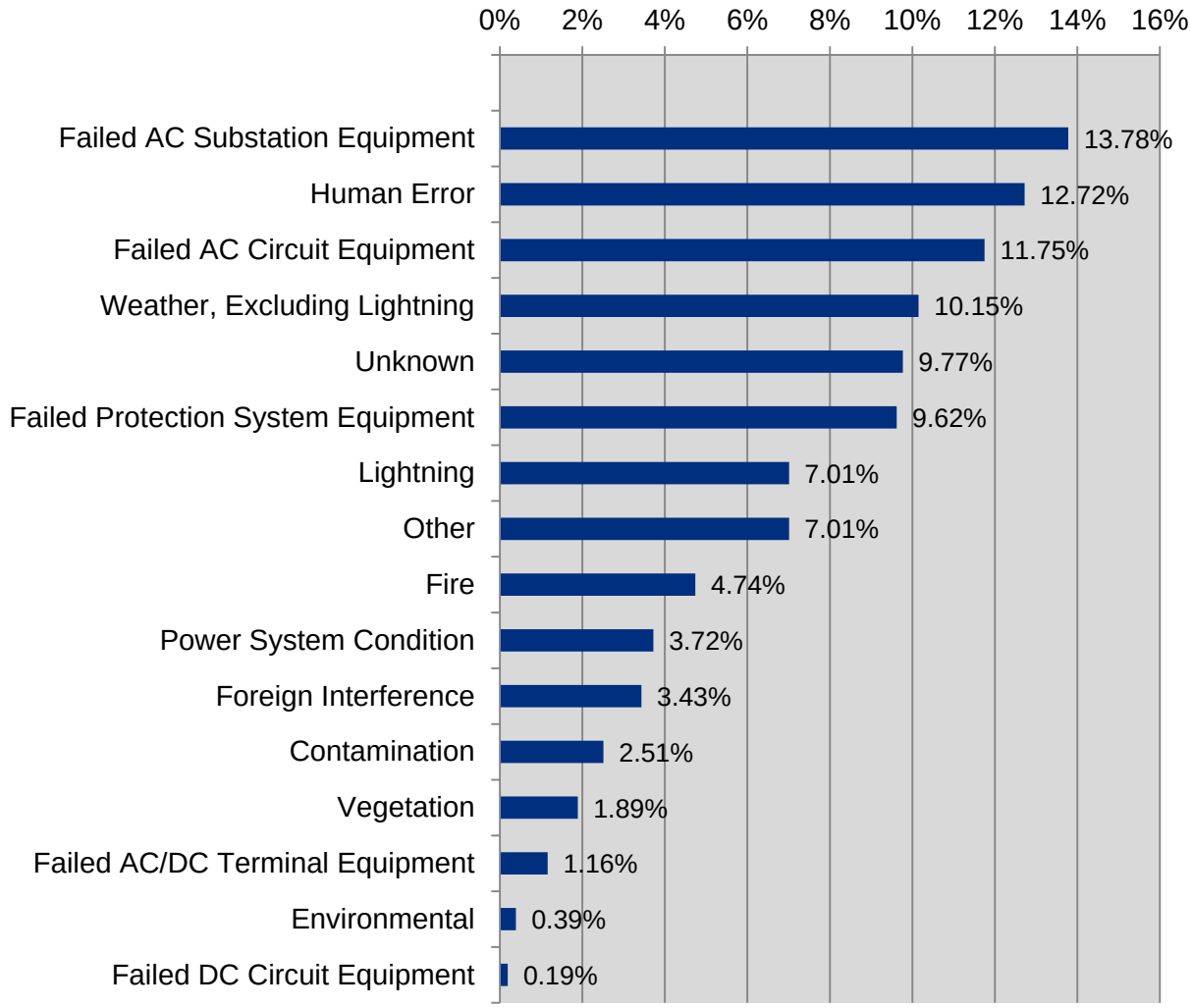
[8] DHS, *Regional Resilience Assessment Program Fact Sheet*, December 2013.

[9] The Federal Government began to examine potential threats to critical infrastructure in the 1990s as a result of incidents of domestic and international terrorism. President Bill Clinton issued Executive Order 13010 in 1996, which identified the Nation's critical infrastructure sectors and established a Presidential Commission on Critical Infrastructure Protection (PCCIP) whose objective was to recommend a comprehensive national infrastructure protection policy and implementation strategy.

[10] DHS, OCIA, and Office of Intelligence and Analysis (I&A), *Infrastructure Protection Note: Most Significant Activity Surrounding Tactics, Techniques, and Procedures Against the Electricity Subsector*, March 26, 2014.

damage. Such threats and hazards can cause extensive damage to electric power systems, but due to system resiliency the effects may not result in significant power outages.

In 2012, the U.S. transmission grid experienced 2,068 sustained automatic outages, which lasted for a total of 71,822 hours.[11] The U.S. Energy Information Administration's (EIA's) *2014 Electric Power Annual* reports that sustained outages on the transmission-level grid were primarily caused by equipment failure, weather, and human error (Figure 2).[12]



Other includes automatic outages for which the cause is known, but is not included in the above list.

Foreign Interference includes objects such as aircraft, machinery, vehicles, kites, events where animal movement or nesting impacts electrical operations, flying debris not caused by wind, and falling conductors from one line into another.

FIGURE 2.—U.S. Transmission Circuit Sustained Automatic Outage Counts for 2012.[12]

[11] An automatic outage results from the automatic operation of a switching device, causing an element to change from an "in-service" state to a "not-in-service" state. A sustained outage is an automatic outage lasting 1 minute or more. DOE, U.S. Energy Information Administration (EIA), *Electric Power Annual*, Table 8.13. A, January 2014, accessed Jan. 31, 2014, www.eia.gov/electricity/annual/.

[12] Ibid.

DEPENDENCIES, INTERDEPENDENCIES, AND POTENTIAL IMPACTS

The resilience of a community or region is a function of the resilience of its subsystems, including its critical infrastructure, economy, civil society, and governance (including emergency services). Resilience can be highly complex due to the dependencies and interdependencies that exist within infrastructure systems, the regions they serve, and the potential for cascading consequences. The loss of electric power within a community can happen at any time as the result of faulty equipment, severe weather, flooding, cyberattack, vegetation control, accident, or sabotage. The loss of electric power is not just an inconvenience for the utility customers. Its impacts can quickly cascade to other lifeline systems, including the Water and Wastewater System Sector, Communications, Transportation, and IT, resulting in the loss of services necessary to the community's economy, public health, and safety. Backup power supplies can mitigate these cascading effects in some cases. Understanding these dependencies and interdependies are important keys to building and maintaining resilent electric power delivery systems.

Electric power substations are an important component of the electric power delivery system, and provide a useful study of the system's dependencies and interdependencies. The following sections will discuss the dependencies of substations on three critical infrastructure services—electric power, communications, and IT—and the dependencies of other critical infrastructure on the electric delivery system. DHS assessment data from the RRAP and the Enhanced Critical Infrastructure Protection (ECIP) program, in which DHS partners with State and local agencies and the private sector to conduct voluntary assessments of a large number of critical infrastructure facilities, was analyzed to determine potential dependencies and resilience of the electric power delivery system.[13]

ELECTRIC POWER SUBSTATIONS

Since January 2011, DHS has conducted 41 assessments of distribution and transmission substations to collect data on substation dependencies and resilience.[14] Of the 41 substations assessed, 59 percent depend upon an external source of electric power for on-site operations, 62 percent depend on communications, and 77 percent depend on IT to maintain operations. Electric power, required to operate substation automated switches and supervisory control and data acquisition (SCADA) equipment, is often provided from a station service line, rather than from the power passing through the station. Any interruption to these control systems, including the loss of electric power, can mean the loss of substation functionality and the potential subsequent loss of power to other critical infrastructure assets (e.g., to communication and IT facilities; a critical infrastructure interdependency).

[13] Site assessments under the ECIP and RRAP are voluntary; they may not be representative of the entire sector. The information and data from the RRAP and the Infrastructure Survey Tool **(**IST, on which the ECIP security survey resides) are often protected as For Official Use Only or as Protected Critical Infrastructure Information; the information provided below has been sanitized to remove any facility, system, or regional references.

[14] There are 10,287 transmission substations and 2,179 distribution substations in the United States, according to the DOE, *The Electric Delivery System*, accessed May 10, 2013, www.ewp.rpi.edu/hartford/~stephc/EP/Research/Waste% 20Cycle/factsheet.pdf.

There are many factors that determine the criticality of a particular substation. How a substation is connected to the facilities that it serves or to the surrounding transmission system affects its role and contribution to the overall resilience of the interconnected grid. For example, a substation that acts as a single source of electric power to a critical facility is more important to operations than a substation that is connected in a looped fashion with other substations and the critical facility. Similarly, a transmission substation that is connected with other surrounding substations and transmission lines may be less critical if disrupted.

Fifty-four percent of all the substations assessed by DHS that depend on external electric power have backup electric generation. Further, substations that have no backup generation capability, 15 percent of the 41, would be expected to experience 67 to 99 percent degradation in operations. Of those substations that depend on communications to operate, 89 percent have alternate or redundant capability and could maintain at least 67 percent of their full operations. However, of those substations that depend on external IT services, only 13 percent could maintain at least 67 percent of full operations if IT services were lost.

Recovery may require considerable time and effort to restore a substation's significant assets to full operation depending on what equipment is damaged. Substations include transformers, circuit breakers, disconnect switches, bus-bars, shunt reactors, shunt capacitors, current and potential transformers, and control and protection equipment. Among the more difficult to replace and repair components include high-voltage transformers and circuit breakers. There are also switches and circuit breakers located elsewhere throughout the delivery system, not necessarily at substations, that are essential for isolating (de-energizing) segments of the network for inspections and repairs. Depending on the variables such as extent of damage and availability of equipment and personnel, full restoration of a substation can take from 9 days to more than 1 year.[15]

Data Collection and Levels of Facility Degradation

The ECIP Initiative collects data through the Infrastructure Survey Tool (IST), a secure web-based tool that provides the ability to collect, process, and analyze survey data in near real time. Data collected during site visits are consolidated in the IST and then valued and weighted, which enables DHS to develop metrics; conduct sector-by-sector and cross-sector vulnerability comparisons; identify security gaps and trends across critical infrastructure sectors and sub-sectors; and establish sector baseline security survey scores.

The term "dependency," as used in the IST and reported here, is defined as the reliance of a facility on an outside/external utility or service to carry out its "core operations."

Degradation addresses how soon a facility will be impacted and to what extent if the source is lost. Data on degradation are gathered in the IST as a mutually exclusive set of answers: 0 percent degradation, 1 to33 percent degradation, 34 to66 percent degradation, 67 to99 percent degradation, or 100 percent degradation.

Data are also collected on the existence of backup generation, duration of backup generation without refueling, and recovery time after external infrastructure service is restored.

[15] Argonne National Laboratory, Restore©, *Modeling Interdependent Repair/Restoration Processes*, accessed February 26, 2014, www.dis.anl.gov/projects/restore.html.

IMPACTS TO CRITICAL INFRASTRUCTURE FROM LOSS OF ELECTRIC POWER

Impacts from the loss of electric power vary greatly depending on the severity and location of the loss within the system. Isolated incidents at a single distribution substation, or along individual distribution lines, can create localized outages that may last several hours. An incident at a transmission or subtransmission substation, or along a high-voltage transmission line, can create more widespread and significant impacts if appropriate protective measures outlined in contingency plans and operating guides are not achievable by system operators. The loss of multiple substations and lines, which can occur during a large-scale weather event like a hurricane, may result in the loss of electricity to millions of customers. As a result of the diversity of impacts from disrupted substations or transmission lines, restoration of the power transmission and distribution system can take days to weeks, depending on the ability to bypass damaged substations or disrupted lines using the built-in resilience of the interconnected grid. Historically, the loss of electric power delivery systems has resulted in some degree of cross-sector impacts, particularly to other lifeline systems.

Figure 3 provides a notional depiction of the physical interconnection of lifeline systems to a distribution substation and the impacts of the loss of electric power. Of the total sites that DHS assessed through RRAP and ECIP surveys, 90 percent depend on electric power for operations.[16] To illustrate the possible cross-sector impacts, data gathered from selected critical lifeline systems, including Water, Wastewater, Transportation, Communications, and IT facilities, were used to provide information about the ability of critical infrastructure facilities to operate during an electric power outage. The dependency data for each asset in Figure 3 were based on the median resilient facility within each lifeline system.[17]

As the results in Figure 3 indicate, the significant cross-sector impacts that occur from the loss of electric power, including the loss of SCADA functions for other lifeline sectors, underscore the importance of enhancing the resilience of the electric power delivery system. In addition, an in-depth knowledge of the resilience capabilities of lifeline system assets is crucial to effectively prioritizing response and recovery activities prior to, during, and after an event.

The example in Figure 3 depicts that water treatment plants dependence on electricity to supply raw water, whether by pumping from groundwater or surface water; for treatment processes (e.g., rapid mixing); or for pumping treated water to the distribution system. For water systems with elevated distribution service areas, loss of electricity to pumps can result in isolation of portions of the system. Similarly, wastewater treatment plants depend on electricity for the collection of wastewater (e.g., lift stations) and for treatment processes.[18]

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[16] Between August 2009 and December 2012, 3,352 sites in all 16 DHS Sectors received DHS visits.

[17] The median resilient facility is based on the value of the overall Infrastructure Survey Tool Resilience Measurement Index, or RMI. The mean value of a variable, also commonly referred to as the average, is calculated by summing the observed values and then dividing by the total number of observations. The max is the highest RMI for any of the 41 substations in the comparison group and the min is the lowest. Argonne National Laboratory, *Resilience: Theory and Applications*, January 2012, www.dis.anl.gov/pubs/72218.pdf.

[18] Electric Power Research Institute (EPRI), *Water & Sustainability (Volume 4): U.S. Electricity Consumption for Water Supply & Treatment—The Next Half Century*,March 2002, accessed February 27, 2014, www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001006787.

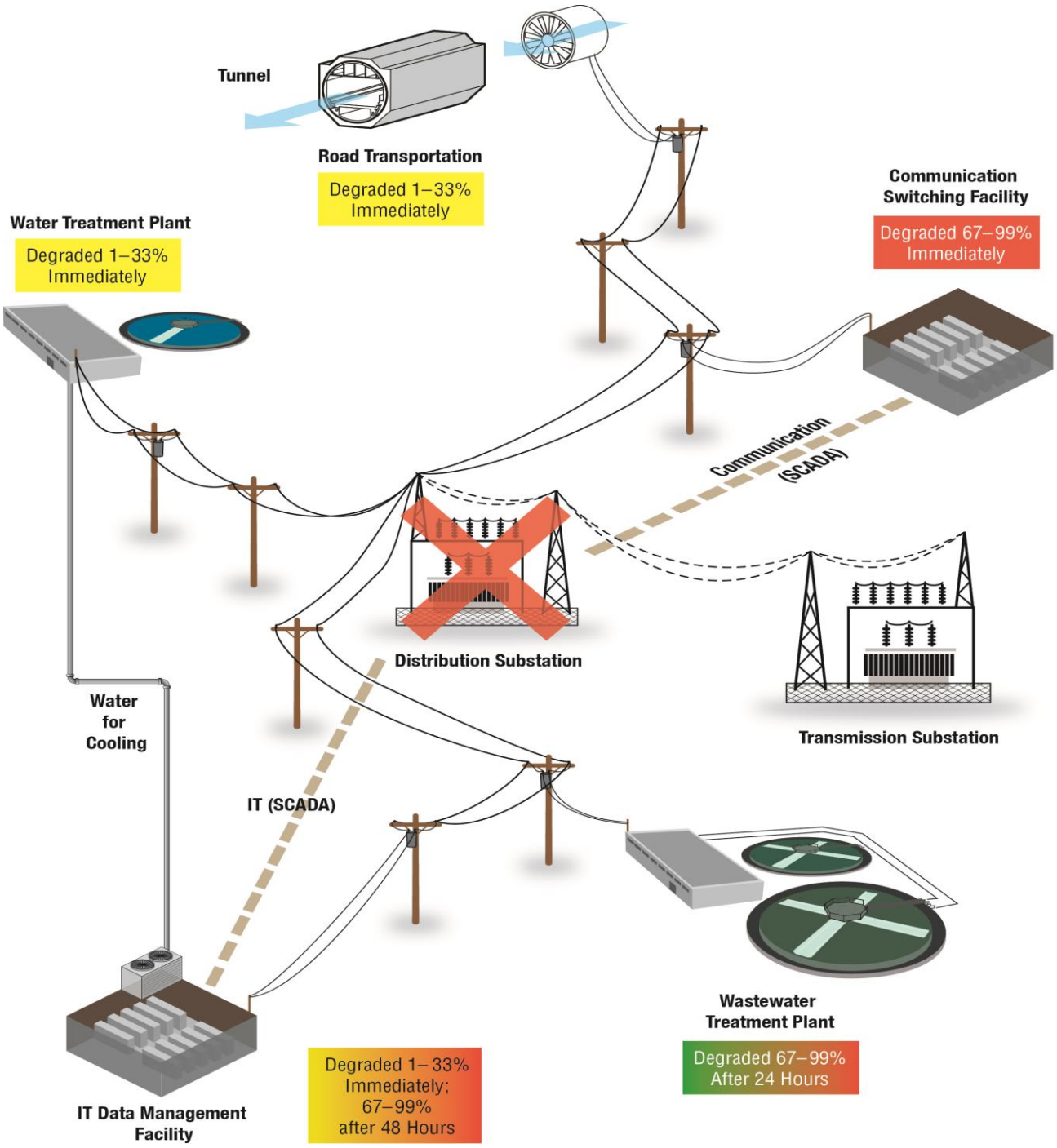

FIGURE 3.—Notional Impacts to Critical Infrastructure from the Loss of Electric Power Brought On by the Loss of a Distribution Substation (Courtesy of DHS and Argonne National Laboratory).

The data that was collected and illustrated in Figure 3 shows up to 33 percent of water treatment plant operations could be immediately degraded due to loss of external electric power. DHS infrastructure site assessments indicated that 91 percent of water treatment plants and 82 percent of wastewater treatment plants have backup generators. Failure of both external electric power and backup power systems can result in severe consequences for water treatment systems. For example, in 2011, power outages during Hurricane Irene on the East Coast in August and the October snowstorm in the New England area resulted in a combined total of 50 sewage spills that discharged millions of gallons of untreated or partially treated sewage into Connecticut's waterways when backup power systems failed at a number of facilities.[19]

Due to the dependencies and interdependencies of critical infrastructure sectors, cascading failures are a potential consequence of any incident. An example of a cascading failure is when wastewater treatment systems fail due to a power outage and discharge untreated or partially treated sewage to waterways that supply raw water to downstream drinking water treatment plants. If a downstream water treatment plant does not have a disinfection process capable of treating contaminated raw water, drinking water supplies will also be impacted—even if that plant has electric power.

Communication switching facility operations can be severely degraded due to a loss of external electric power, as depicted in Figure 3. Although 71 percent of communication facilities that DHS assessed have backup generators to maintain switching functions, a prolonged electric outage requires the delivery of fuel. In addition, although many cell towers may have battery backup, such systems will last from a few hours to a day. IT facilities may have uninterruptible power supplies (UPSs), but these too are of limited duration. DHS data indicates that 88 percent of IT data management facilities surveyed use UPSs to maintain operations.

DHS infrastructure assessments of road transportation, specifically tunnels, as shown in Figure 3, indicate that up to 33 percent of assets would experience immediate functional degradation from a loss of external electric power. Roadway tunnels are dependent on electric power for core operations (e.g., lighting, traffic control equipment, and ventilation). While most assets have some type of backup generator, complete power loss could impact traffic levels to keep carbon monoxide at a safe-level. Traffic flow would also cease in tunnels if water began to enter the tunnels due to water pump power loss.

[19] The Hartford Courant, *Severe Storms Led to Sewage Spills Across State*, December 31, 2011, accessed February 27, 2014, http://articles.courant.com/2011-12-31/health/hc-storm-seweragespills-0101-20111231_1_gallons-of-raw-sewage-spills-backup-power.

RESILIENCE ISSUES AND BEST PRACTICES

Table 1 presents commonly observed resilience issues and best practices summarized for three categories of users: electric power provider systems and facilities, community risk management organizations (i.e., State or local emergency operation centers or fusion centers), and any critical infrastructure asset or system that depends on electric power (i.e., electric power customers). The issues and best practices listed in Table 1 were identified in RRAPs and from among the results of the ECIP assessments, as well as general literature reviews.[20] The information is meant for general application across the electric power delivery system, impacted sectors, and customers. The resilience issues and best practices identified may apply to other regions, other facilities, or other types of facilities. See the Appendix for supporting resources and references.

TABLE 1.—Resilience Issues and Best Practices.

FOR ELECTRIC POWER PROVIDER SYSTEMS AND FACILITIES
Electric utilities may have issues with equipment failures that impact rapid response and recovery
▪ Continue with Smart Grid programs and develop capital improvement plans that incorporate Smart Grid technology over time as aging equipment is replaced or retrofitted.
The electric distribution grid may lack adequate design redundancies
▪ Use flow modeling to identify areas that can be impacted by single points of failure. In coordination with the State Homeland Security agency, identify lifeline system assets within the potentially impacted service territory and work with those assets to identify measures that can be taken to mitigate outages. ▪ Review restoration plans and resources to determine the availability of specialized equipment, crews, and materials. ▪ Consult with State officials to determine whether the State can support transmission network upgrade projects through emergency or reliability programs.
High-consequence substations may not have the latest technology
▪ Conduct a cost-benefit analysis that examines the application of automated intelligent switching to the transmission lines supporting high-consequence substations. ▪ Work with State and local emergency managers and energy assurance planners to apply such technology where the benefits outweigh the costs.
Electric equipment lacks protection from natural hazards, accidents, or sabotage
▪ Determine whether equipment is at risk to natural hazards, accidents, or sabotage. ▪ Harden at-risk equipment against natural disasters, such as flooding. Move at-risk equipment to higher ground or build flood containment structures. Develop flood mitigation plans for at-risk substations. ▪ Install protective measures, such as fencing and bollards, around equipment that is at risk of sabotage or accident and, if necessary, install fire/blast walls to protect adjacent equipment.

[20] Resilience information gathered via the RRAP and ECIP assessments are often protected as For Official Use Only or as Protected Critical Infrastructure Information; the information in Table 1 has been sanitized to remove any facility, system, or regional references.

FOR COMMUNITY RISK MANAGEMENT ENTITIES

State and local emergency management agencies lack information on equipment and resource reserves in other agencies or neighboring States or communities

- Work with the local utility to understand private sector capabilities and resources.
- Develop memoranda of understanding or agreements with utilities for resource sharing and identify other areas where the Government and private sector can share resources.

State and local emergency management agencies lack information on prioritizing fuel deliveries to critical governmental emergency response agencies and to privately owned, critical infrastructure facilities that are dependent on emergency generators or need fuel for repair vehicles

- Governmental agencies should ensure that emergency operations centers have identified critical equipment and determined the emergency generation capabilities, including fuel needs.
- State and local energy assurance plans should include provisions for the distribution of petroleum fuels to priority government and privately owned critical infrastructure and lifeline sector customers following a disaster.
- In the event of severe fuel shortages during which suppliers need to ration the fuel supply for an extended period (1 month or longer), implement a statewide set-aside program or priority end-user program.
- Review governmental contracts to assess the potential impact of Excuse by Failure of Presupposed Conditions provisions under Uniform Commercial Code Section 2-615, as adopted in each State.

Citizens need to be better informed on the necessary steps to take to help ensure personal resilience and preparedness for prolonged electric power outages

- Conduct outreach to inform citizens of steps they can take to prepare for a blackout; such outreach will also aid local utilities by reducing calls for information and damage/distress calls.

Emergency response agencies may not always communicate effectively with the population

- Use social media to communicate in disaster preparation, response, and recovery.

Electric utilities are not part of the State and local emergency response planning process

- To improve communication among electric distribution providers, customers, and State and local emergency response organizations, ensure that utility reporting content and point-of-contact information are built into State and local emergency response plans.

State and local energy assurance plans may not be incorporated into emergency planning, are not updated, and are not exercised regularly

- Incorporate energy emergencies into State and local exercises.

  Link energy assurance plans with Emergency Support Function-12 activities to better engage with industry.[21]

[21] Emergency Support Function (ESF) #12 – Energy is intended to facilitate the restoration of damaged energy systems and components when activated by the Secretary of Homeland Security for incidents requiring a coordinated Federal response. Under Department of Energy (DOE) leadership, ESF #12 is an integral part of the larger DOE responsibility of maintaining continuous and reliable energy supplies for the United States through preventive measures and restoration and recovery actions. http://www.fema.gov/media-library-data/20130726-1825-25045-9530/emergency_support_function_12_energy_annex_2008.pdf, accessed July 9, 2014.

- Ensure participation by States in regional exercises conducted by DOE and the National Association of State Energy Officials (NASEO).
- Review and revise the State and local energy assurance plans at least annually and after each energy emergency to ensure that the plans contain the latest information and best implementation procedures.

Functions, vulnerabilities, and impacts of the loss of electric power on other critical infrastructures (e.g., water, wastewater, natural gas, petroleum, and communications) are not well understood by emergency planners and responders

- Develop an Interdependency Operational Plan (IOP) and Decision Support Tool (DST) to use in conjunction with current Emergency Operations Center capabilities. Work with critical infrastructure owners and operators to obtain necessary information on critical infrastructure assets. Elements to consider in developing the IOP and DST include (1) protected, methodological data collection; (2) detailed analysis of asset dependencies and interdependencies; (3) alternative means of providing the service; and (4) distinct recovery time objectives (RTOs).

FOR ELECTRIC POWER CUSTOMERS

Electrical equipment and backup generators lack protection from natural hazards, accidents, or sabotage

- Identify equipment that is at risk of flooding, surge, accident, or sabotage.
- Consider hardening facility-owned electrical equipment and emergency generators against unauthorized access.
- Develop storm surge and flood mitigation plans for at-risk electric equipment and emergency generators; move at-risk equipment to higher ground.

There is a lack of redundancy in electric power service

- Consider requesting redundant service lines that can support the full facility load, are not collocated with other utility corridors, and are connected to different utility subsystems.
- Consult with utility providers, which often have programs to provide expert technical consultation to determine the best configuration for critical service lines.

Customers have not assessed the electric power dependencies of their core functions and have not determined the business continuity impacts from the prolonged loss of externally supplied electric power

- Conduct a business impact analysis to ensure that backup generation has sufficient capacity to support all critical functions (e.g., security systems and communication and IT equipment) simultaneously and then define the onsite emergency power capability (e.g., safe system shutdown versus full core function capability versus reduced core function capability).
- Conduct a feasibility study to determine required onsite emergency power needs before selecting generation equipment or incorporating provisions for onsite emergency power generation into business continuity plans.
- Determine the amount of fuel that would need to be stored onsite to allow continued operation of emergency generation equipment in the event of fuel supply disruptions.

Customers may not have contracts in place to ensure continued delivery of fuel needed for onsite emergency power generation following a major disaster

- Review fuel contracts to determine the potential impacts of Excuse by Failure of Presupposed Conditions provisions under Uniform Commercial Code Section 2-615, as adopted in each State.
- For critical lifeline system assets, consider arranging for multiple fuel providers in the event of a prolonged outage.
- Consult with manufacturer of emergency generator equipment to determine its potential to use alternative fuels (e.g., diesel and natural gas or diesel and jet fuel).

Customers have not tested emergency generators at load to ensure that they will operate as designed

- Conduct scheduled load tests on emergency generators.
- Enroll emergency generators in a preventative maintenance program (e.g., through a contracted service).
- Ensure that facility personnel are trained in operation of the emergency generation equipment.

Critical infrastructure customers lack emergency planning that includes addressing the loss of electric power and do not train or exercise this contingency

- Develop or amend emergency or business continuity plans to address the long-term loss of electric power; train personnel in implementing backup equipment and alternate operational procedures; and finally, exercise plans at least annually.
- Investigate contingency plans with electric power providers, including priority service restoration based on criticality to disaster recovery.
- Review electric utility service contracts to confirm that firm electric service is available for critical functions and understand contractual provisions for the utility's voluntary reduction options, as well as its load-shedding priorities.

Critical infrastructure customers lack emergency power capability to improve core function resilience

- Install onsite emergency generators, or consider installing appropriate connections and entering into contracts for the delivery of portable emergency generators, following an emergency event.
- Place emergency generators away from other electrical equipment so that a single event will not impact both main power and emergency power equipment.
- Consider alternatives to emergency generators, including using large equipment with electric generating capabilities such as railroad locomotives, ships, or even tractors.
- Install battery backup systems for safe shutdown to prevent equipment damage from loss of electric power.
- Many electric power providers will provide consultation to determine whether onsite generation equipment (distributed generation) is feasible and cost-effective; make use of this resource, if it is available.

APPENDIX

RESILIENCE ISSUES AND BEST PRACTICES: REFERENCES AND RESOURCES

The following references provide more in-depth information on the Electric Transmission and Distribution Segment, including vulnerabilities, gaps, resilience technology, and other sector-specific guidance.

ABB

- *U.S. Rapid Recovery Transformer Initiative Succeeds Using Specially-Designed ABB Transformers*, October 4, 2012, www.abb.us/cawp/seitp202/9a9f00ef6e90dd00c1257a7e0042e142.aspx.

Argonne National Laboratory

- *Resilience: Theory and Applications*, January 2012, www.dis.anl.gov/pubs/72218.pdf.

DOE

- Smart Grid Investment Grant Program (a public-private partnership to accelerate investments in grid modernization), July 2012, http://energy.gov/oe/downloads/smart-grid-investment-grant-program-progress-report-july-2012.
- *Large Power Transformers and the U.S. Electric Grid,* June 2012, http://energy.gov/oe/downloads/large-power-transformers-and-us-electric-grid-report-june-2012.
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