NIST Special Publication 1190GB-5

Guide Brief 5 – Assessing Energy System Dependencies

This publication is available free of charge from:
https://doi.org/10.6028/NIST.SP.1190GB-5

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Community Resilience

NIST Special Publication 1190GB-5

Guide Brief 5
Assessing Energy System Dependencies

This publication is available free of charge from:
https://doi.org/10.6028/NIST.SP.1190GB-5

December 2016

U.S. Department of Commerce
Penny Pritzker, Secretary

National Institute of Standards and Technology
Willie May, Under Secretary of Commerce for Standards and Technology and Director

National Institute of Standards and Technology Special Publication 1190GB-5 Natl. Inst. Stand. Technol. Spec. Publ. 1190GB-5, 7 pages (December 2016)
CODEN: NSPUE2

This publication is available free of charge from:
https://doi.org/10.6028/NIST.SP.1190GB-5

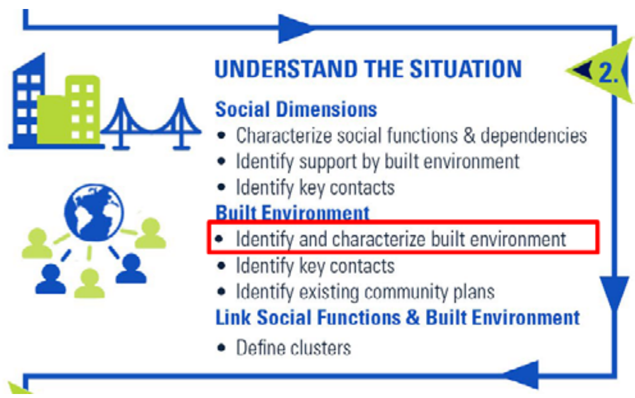
This page intentionally left blank.

Guide Brief 5 – Assessing Energy System Dependencies

Applicable Section(s) of Guide: Volume 1, Section 3.2, Characterize the Built Environment, p. 35

Guide Briefs supplement the Community Resilience Planning Guide for Buildings and Infrastructure Systems (NIST SP1190)

Purpose and Scope



A major aspect of characterizing the built environment is identifying key infrastructure dependencies that may exist. Some of these dependencies are obvious; others are not. This Guide Brief focuses on Step 2, understanding the built environment, and focuses on understanding dependencies from an energy system perspective. It is intended to help the collaborative planning team understand where energy is a critical dependency for other systems in the community. The Guide Brief is also useful for planners who work with building inspection departments, planners for first responders, and planners who are responsible for shelters.

1. Identifying and Understanding Energy System Dependencies

The Nation's energy system consists of millions of electricity, oil, natural gas, coal, nuclear, and renewable energy assets that are geographically dispersed and interconnected. Energy infrastructure needs to be operating properly for other infrastructure systems—such as transportation, communications, water and wastewater systems—to maintain their functionality. For example, buildings require electricity to provide lighting, heating and cooling, food preservation and preparation, and power for electronic devices. Transportation systems, such as light rail and ports, require energy for their operations. Fuel supplies are needed for freight rail and vehicles used by recovery personnel to conduct debris removal, inspections, and other recovery operations. There are also dependencies within the energy infrastructure itself. For example, petroleum refineries and pipeline pumping stations depend on a reliable electricity supply, while backup generators and utility maintenance vehicles depend on diesel and gasoline fuel [Department of Homeland Security and Department of Energy 2007].

Not only is the energy infrastructure interconnected, it is also complex, whereby local failures can have regional impacts. As early as 1997, a report from the President's Commission on Critical Infrastructure Protection [1997] noted that energy is the lifeblood of our interdependent infrastructure systems, and routine disturbances can cascade into a regional outage. That Commission also noted that technical complexities may permit vulnerabilities to remain unrecognized until a major failure occurs. The August 2003 blackout in the Midwest and Northeastern United States and Canada was triggered by a routine disturbance [Peerenbomm et al 2007]. A series of incidents began with a power line sagging into a tree in Cleveland, Ohio, which was escalated by a control system software bug, and cascaded across critical infrastructure systems, resulting in massive power losses and degradation of essential services across numerous states and into Canada. While communities cannot anticipate such events, they can be ready to respond and recover rapidly at a local level by coordinating with local power representatives.

In Step 2 of the Guide, understanding the situation with respect to energy systems can be informed by an energy assurance plan. It is necessary that planners understand the dependent relationships among energy infrastructure systems, key local services, and valued community assets. This understanding can help plan for additional energy-related resilience such as redundancy, hardening, or backup power systems, and help mitigate the possible consequences of large-scale failures of energy systems.

Table 1, developed by the Public Technology Institute for its *Local Government Energy Assurance Guidelines* [2011], lists services that can be disrupted through an energy outage.

Table 1. Energy Source Disruption Service Impacts [Public Technology Institute 2011]

Essential Services	Potential Effects by Energy Type	
	Electric Power Systems	Natural Gas/Oil
Banking and finance	Financial transactions; HVAC systems	Fuel for heat, generators, and facilities
Telecommunications (landline, cellular, and cable)	Switches and communication facilities: distribution, supervisory control and data acquisition (SCADA) systems, customer service and repair crew communication	Fuel for heat, generators, and facilities
Transportation	Electric public transportation; signal and control system; transport of fuel and shipping of goods and materials	Fuel and lubricants for vehicles and facilities; transport of fuel and shipping of goods and materials
Water supply	Control systems, lift stations, and facilities: transportation of water (pumps); cooling and emission controls; water transport for emergency response	Gas-fired HVAC systems; fuel/water pumping/processing, etc.
Governmental systems	Facility HVAC systems; lighting; telecommunications; battery charging (e.g., 800 MHz radios); emergency response and protective services such as EMS, police, and fire	Gas-fired HVAC systems; fuel/water pumping/processing, etc.
Emergency response and protective services	Base-to-field communications; recharging of office and field equipment; re-rerouting of impacted individuals/animals to facility with electrical service	Electrical outages for gas-fired power generation with similar impacts as under power systems
Sewage systems	Sewage pumping and treatment for stationary, local/regional scale systems and temporary site-based pump and treat systems	Curtailment of sewage pumping and treatment for stationary, local/regional scale systems and temporary site-based pump and treat systems if electrical systems are gas/oil fired

To help communities understand the local energy services and the inter-dependencies, they can ask energy system representatives the following questions (note that there may be other questions depending on local circumstances):

Example questions to help communities can identify energy infrastructure dependencies
• **Energy Sources:** Who are the local energy suppliers? Who are the key points of contact at each company/supplier that can assist in helping the community understand energy infrastructure dependencies? • **Generation Fuels:** What fuels are used to generate local electricity? Coal, natural gas, other? How are these fuels transported? • **Energy Infrastructure:** What is the local energy infrastructure in terms of facility and station locations and routing? Is this information available in one place (map, file, etc.)? • **Energy Distribution:** How many independent routes are there from for the energy source (for electric power, natural gas, liquid fuels) to the community? Is each one capable of supplying the whole community? Is the energy network in the community fully interconnected or are there areas that can only be supplied from one source? Where are the key single points of failure? Are there critical spares available for the single points of failure? • **Gas Supplies:** What are the routes of the major natural gas pipelines within the community and do they cross under (or very close to) critical facilities? • **Liquid Fuel Supply:** Where do liquid fuels (e.g. gasoline, diesel, etc.) come from – pipelines, tank farms, distributor sites (commonly known as “racks” in the industry)? How much supply is stored locally by the distributors? How much of each fuel is stored by the community and do these facilities have back up electric power sources? Are there any gravity fed systems locally? • **System Interdependencies:** What other local infrastructure systems require reliable power or fuel supply to operate, such as transportation, water, buildings, and communication? • **Event Response:** Which physical assets in each infrastructure system are critical to emergency operations and recovery efforts within the community? What are practical ways to provide energy assurance to these assets following hazard events? • **Social Vulnerabilities:** Which social institutions are most affected by the loss or degradation of energy supply? What are practical ways to provide energy assurance to these communities?

Creating and maintaining a map that shows the locations of energy facilities, with notes on ownership, criticality, routes for electricity, natural gas, liquid fuel pipelines, etc. is a step communities should take with the assistance of the asset owners (e.g., utilities, pipeline owners, etc.). It is also important to have a physical copy available so it is accessible in following a hazard event when access to digital copies may not be possible.

There are numerous approaches to identifying dependencies. Finding a way to visualize them is helpful in communicating the issues among the collaborative planning team’s various infrastructure representatives. Figure 1 illustrates a way to quickly visualize the impact of electric energy failure to various other systems and services. This kind of visualization can be prepared for each infrastructure system with the most critical dependencies that need to be mitigated shown in the diagram. This diagram is not intended to be comprehensive. The contents (i.e., dependencies) will vary by community and may have different infrastructure systems and community sectors included in the diagram. The electricity slice of the diagram is not filled in because “electricity failure” is at the center of the diagram, with the focus of the diagram being on external dependencies rather than internal dependencies.

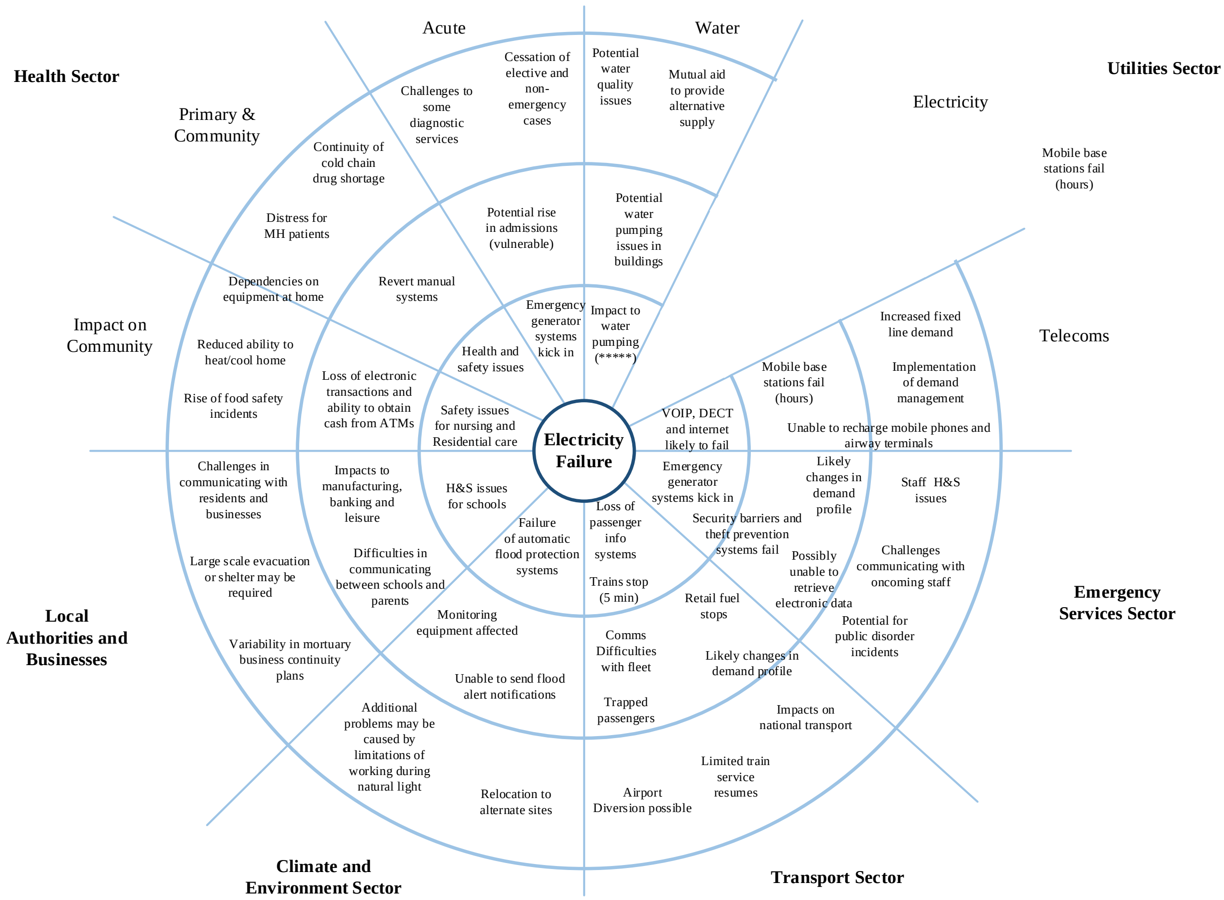


Figure 1. Infrastructure dependencies on a failure in electrical power distribution. The concentric rings, starting nearest the center, represent primary infrastructure losses, secondary infrastructure losses, and losses of social function, respectively. [Adapted and Redrawn from Hogan 2013 – http://www.slideshare.net/mtthwhgn/anytown160513-final]

Once dependencies are identified, an analysis of the dependencies is needed to address the linkages within and among:

- Facilities and assets
- Networks (physical and cyber)
- End-to-end systems
- Communities, regions and states
- Cross-national borders

Disrupting these linkages (physical or cyber) can trigger cascading and escalating failures, or common cause failures of co-located infrastructure systems [Scalingi and Folga 2013]. This issue again highlights the need to understand where a community's key assets are physically located and whether they share the same physical location, access routes, or other physical, logical, or virtual elements with each other.

2. Resources to Assess Energy System Dependencies

The following are examples of resources that may be useful to communities when assessing and gaining an understanding of their dependencies from an energy perspective:

Infrastructure Lessons Learned for Energy and Regional Resilience. At the 2013 U.S. Department of Energy Interdependencies Workshop, Scalingi and Folga [2013] discussed how energy dependencies have impacted preparation, response, and recovery from recent hazard events. To illustrate the importance of understanding dependencies, the impacts of dependencies for the following hazard events were discussed (https://www.naseo.org/Data/Sites/1/events/energyassurance/2013-12-02/scalingi-and-folga.pdf):

- ***Northeast Winter Storm – February 2013.*** The Northeast Winter Storm caused massive power outages creating additional community issues beyond the weather itself. Gas stations could not pump gas, traffic lights could not function, buildings could not provide basic life support, and other infrastructure systems could not function. The outage left 700,000 customers without power and created gasoline shortages, traffic disruptions and car accidents, and airports were affected with more than 6,300 flights cancelled in the New York City area.
- ***Hurricane Sandy – October 2012.*** Hurricane Sandy caused widespread flooding that impacted roads, tunnels, and subways. It also resulted in power outages that affected multiple states. The region faced gasoline shortages in the impacted areas since supply routes were inaccessible, which led to implementation of odd/even purchase plans. Five hospitals and 30 nursing homes/adult residential facilities were evacuated due to power loss. The loss of power also resulted in the New York Stock Exchange being closed for trading for two days.
- ***Southwest Blackout – September 2011.*** The Southwest Blackout was the largest blackout in California history, resulting in loss of power to 7 million people in western Arizona, southern California, and Mexico. The outage was the result of 23 distinct events that occurred on 5 separate power grids in a span of 11 minutes [MacDonald and Morgan 2011]. The outage resulted in traffic signal outages, causing gridlock on the roads in San Diego area. The loss of power also resulted in millions of gallons of untreated sewage being discharged into the water off the coast of San Diego.

Towards a Common Language of Infrastructure Interdependency. Carhart and Rosenberg [2015] provide topics to initiate and facilitate discussion among stakeholders with respect to dependencies and to help characterize relationships qualitatively (http://discovery.ucl.ac.uk/1469380/1/125-130.pdf).

Incorporating Logical Dependencies and Interdependencies into Infrastructure Analyses. Petit and Lewis [2016] provide an overview of elements that can be used to characterize and assess logical dependencies rather than physical or cyber dependencies. It provides potential methods to operationalize and integrate logical dependencies into resilience methodologies. (http://cip.gmu.edu/2016/02/17/incorporating-logical-dependencies-and-interdependencies-into-infrastructure-analyses/).

Dams and Energy Sectors Interdependency Study. The US Department of Energy (DOE) and Department of Homeland Security (DHS) published a report in September 2011 on a collaborative effort to examine and better understand dependencies between dams and energy. The report emphasizes the impact of weather patterns and the water demand for which directly impacts the amount of water that is available for hydroelectric power generation (http://energy.gov/oe/downloads/dams-and-energy-sectors-interdependency-study-september-2011).

Interdependence of Electricity System Infrastructure and Natural Gas Infrastructure. In October 2011, a memorandum from the Electricity Advisory Committee to the Secretary for Electricity Delivery and Energy Reliability provided a summary of their review of the nations' energy infrastructure. This work was completed to determine potential areas for greater reliability and efficiency. This resource contains a summary of the advisory committee's recommendations (http://energy.gov/sites/prod/files/EAC - Interdependence of Electricity System Infrastructure and Natura Gas Infrastructure Oct 2011.pdf).

Water and Energy Interface. The National Energy Technology Laboratory (NETL) has initiated a Water-Energy Interface Program that is dedicated to assessing dependencies between water resources and energy systems, and developing technical solutions to overcome barriers in the interface (https://www.netl.doe.gov/research/coal/crosscutting/environmental-control/water-and-energy-interface).

3. References

Carhart, Neil, and Ges Rosenberg (2015). *Towards a Common Language of Infrastructure Interdependency.* International Symposium for Next Generation Infrastructure Conference Proceeding: 30 September – 1 October 2014. International Institute of Applied Systems Analysis. Schloss Laxenburg, Vienna, Austria. Viewed November 7, 2016. http://discovery.ucl.ac.uk/1469380/1/125-130.pdf.

Electricity Advisory Committee (2011). *Interdependence of Electricity System Infrastructure and Natural Gas Infrastructure.* Viewed November 7, 2016. http://energy.gov/sites/prod/files/EAC - Interdependence of Electricity System Infrastructure and Natura Gas Infrastructure Oct 2011.pdf.

Hogan, Matthew (2013). *Anytown – Infrastructure Interdependencies and Resilience.* London Resilience Team – London Prepared. Viewed November 21, 2016.

McDonald, Jeff, and Lee Morgan (2011). *Outage had roots in Mexico, too*. Associated Press. Retrieved September 26, 2011. http://www.sandiegouniontribune.com/news/watchdog/sdut-outage-had-roots-in-mexico-too-2011sep16-story.html.

National Energy Technology Laboratory (2016). *Water and Energy Interface.* U.S. Department of Energy. Viewed November 7, 2016. https://www.netl.doe.gov/research/coal/crosscutting/environmental-control/water-and-energy-interface.

Peerenboom, James P., and Ronald E. Fisher (2007). *Analyzing Cross-Sector Interdependencies.* 40th Annual Hawaii International Conference on System Sciences (HICSS'07). http://ieeexplore.ieee.org/document/4076595/.

Petit, Frederic, and Lawrence Paul Lewis (2016). *Incorporating Logical Dependencies and Interdependencies into Infrastructure Analysis.* George Mason University. Viewed November 7, 2016. http://cip.gmu.edu/2016/02/17/incorporating-logical-dependencies-and-interdependencies-into-infrastructure-analyses/

Public Technology Institute (PTI) (2011). *Local Government Energy Assurance Guidelines, Version 2.0.* https://dl.dropboxusercontent.com/u/14265518/leap/PTI_Energy_Guidelines.correx.v2.pdf.

President's Commission on Critical Infrastructure Protection (1997). *Critical Foundations: Protection America's Infrastructures.* The Report of the President's Commission on Critical Infrastructure Protection. https://www.fas.org/sgp/library/pccip.pdf.

Scalingi, Paula, and Steve Folga. *Infrastructure Interdependencies Lessons Learned for Energy and Regional Resilience.* U.S. Department of Energy Interdependencies Workshop, Washington DC, Dec 2, 2013. Viewed November 7, 2016. https://www.naseo.org/Data/Sites/1/events/energyassurance/2013-12-02/scalingi-and-folga.pdf.

References

U.S. Department of Homeland Security, U.S. Department of Energy (2007). *Energy: Critical Infrastructure and Key Resources Sector-Specific Plan as input to the National Infrastructure Protection Plan*, page 17, May 2007. http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/Energy_SSP_Public.pdf.

U.S. Department of Homeland Security and U.S. Department of Energy (2011). *Dams and Energy Sectors Interdependency Study*. Viewed November 14, 2016. www.energy.gov/sites/prod/files/Dams-Energy Interdependency Study.pdf.

Community
Resilience

NIST
National Institute of
Standards and Technology
U.S. Department of Commerce

This publication is available free of charge from:
http://doi.org/10.6028/NIST.SP.1190GB-5