Energy Infrastructure Dependency Curves Simulation Tool User's Guide

Decision and Infrastructure Sciences Division

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by
Molly Finster, Frederic Petit, Janet Ford, and James Butler
Decision and Infrastructure Sciences Division
Argonne National Laboratory

September 2018

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Acknowledgment

The development of the simulation tool has been funded by the U.S. Department of Energy’s (DOE) Office of Energy Policy and Systems Analysis (EPSA) and incorporates information resulting from the Argonne’s Resilient Infrastructure Initiative. The authors gratefully acknowledge the contributions of many people who helped bring this project to its current state of development. More specifically, the authors thank Megan Clifford, Julia Phillips, Charles Macal, and Guenter Conzelmann from Argonne National Laboratory, and Kathleen Marks and Gregory Singleton from DOE EPSA (now known as Office of Policy), without whom this work would not have been possible.

The authors also thank David Dickinson, Stephen Folga, Karen Guziel, Rebecca Haffenden, James Kavicky, Robert Lipkowski, Michael McLamore, Edgar Portante, Shabbir Shamsuddin, and Thomas Wall, who shared their expertise and participated in the workshops, and other Argonne colleagues who made this report possible.

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Executive Summary

Since Rinaldi, Peerenboom and Kelly’s seminal work on critical infrastructure interdependencies (Rinaldi, Peerenboom, and Kelly 2001), researchers have worked to better understand and quantify these interdependencies (Petit et al. 2015; Petit, Verner, and Lewis 2018). Although many studies have focused on understanding connections between systems, few of these studies have been focused on understanding impacts of connections, that is, how consequences from one system cascade into another. Because of the many different types of interdependencies as well as the extreme complexity of the space, understanding of critical infrastructure dependencies and interdependencies is still at an early stage. Even though the research addressing critical infrastructure interdependencies started more than 15 years ago, modeling, simulation, and visualization tools still perform at an intermediate analysis level (Petit et al. 2015). Developing a comprehensive “system of systems” approach to move toward an advanced infrastructure analysis capability presents several challenges to understand infrastructure system operations and the interactions existing between infrastructure systems (Clifford and Macal 2016; Petit, Verner, and Levy 2017).

Through internally funded research, Argonne National Laboratory has compiled a detailed list of infrastructure system assets, upstream dependencies, and impacts for seven lifeline infrastructure sectors and subsectors (i.e., electric power, natural gas, petroleum, telecommunications, water, wastewater, and transportation). A series of workshops were conducted with subject matter experts (SMEs) from each of the lifeline critical infrastructure sectors. Group discussions were held with the SMEs to identify and characterize the extent of interconnectedness between the infrastructures systems.

The workshops specifically addressed the following questions for each asset within each infrastructure system:

- Could the asset operate in the absence of specific resource supply (i.e., resources provided by lifeline infrastructure) and to what extent, or will it shut down?
- Is there typically a backup (or alternative) in place for the asset to mitigate against the loss of the resource supply?
- How long will the mitigation measures operate and to what extent will the asset operate (e.g., fully functional, partially degraded) after the initial loss of resource supply?

In some cases, there can be a great variances in similar assets across infrastructure systems owned by different entities. These variations can be driven by owner risk tolerance, economic costs, geographic, climactic influences, and political-legal environment, to name only a few. Because of these variations, when collecting asset dependency and information, the SMEs were asked to consider the most common type of asset and the most common characteristics of those assets.

The Energy Infrastructure Dependency Curves Simulation Tool uses the concepts of dependency curves proposed by Petit, Wallace, and Phillips (2014) to operationalize the information gathered

during the SMEs’ group discussions and visualize how the loss of resource supplies would potentially affect the performance of energy infrastructure assets over time. This tool focuses on a general depiction of infrastructure upstream dependencies starting with two energy entities: a natural gas-processing plant and an electric power-generating plant.

1 Introduction

Foundational studies of infrastructure interdependencies have attempted to make sense of the complex relationships among critical infrastructure. Beyond understanding the complexity of these interconnections, owner/operators and decision makers have a continuing need for a situational awareness capability tool to move beyond a conceptual understanding toward a more quantified, visual analytic method to enable more detailed real-world analysis and prioritization.

The purpose and development of the Energy Infrastructure Dependency Curves Simulation Tool is to provide a means to display and analyze the complexities of infrastructure dependencies, in a way that is dynamic and can be easily manipulated. The tool focuses on the connections between two infrastructure assets, a natural gas-processing plant that relies on electric power, and an electric power-generating plant that depends on natural gas to produce electricity. The tool allows the user to enter information characterizing each asset and the dependence relationships, including details about core operations, backup function, shutdown, and resumption of service. Output is provided as a visualization of the performance of each asset over time, displaying impact, stages of operation, and resumption to full service. Input can be modified to enable the user to see how different scenarios or decisions would change the outcome. The intent of the tool is to provide the user with the ability to make informed decisions regarding operation of individual asset.

This report presents an overview of the concepts used for developing the Energy Infrastructure Dependency Curves Simulation Tool and a detailed user guide that provides instructions on how to use the tool. Finally, three example scenarios are presented to illustrate dependency curve outputs.

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2 Dependency Curves

A dependency curve illustrates the degradation of an infrastructure asset’s performance over time due to a disruption of a resource that the asset depends on for its operations (Petit, Wallace, and Phillips 2014). The dependency curves combine three categories of information for characterizing the effect of the loss of resource supplies on an infrastructure asset’s operations:

1. Events and mitigation measures. This category characterizes the disruptive event (i.e., loss of supply) and the mitigation measures (i.e., backups and alternatives) and procedures implemented for the continued operation of an asset.
2. Amount of degradation. This category characterizes the different levels of the infrastructure asset’s operations degradation (e.g., degradation with and without using the mitigation measures).
3. Times and durations. This category characterizes the transition between the different levels of degradation, the duration of existing mitigation measures, and the time of occurrence of the initial loss of supply.

Figure 1 illustrates the elements used for generating a dependency curve.

Figure 1 Dependency Curve Components (Petit, Wallace, and Phillips 2014)

The abscissa (i.e., x axis) represents the time, and the ordinate (i.e., y axis) represents the impact on the full operations at the asset, with 0% impact indicating the asset is fully operational and 100% impact indicating operations have fully ceased (i.e., asset shutdown). The curve starts when the resource supply is disrupted, which constitutes the initial impact. The blue-shaded area illustrates the latency time before the initial effect on the asset’s operations. The asset is still operational. At the end of the blue-shaded area, the asset’s operations start being disrupted. At that point, the asset shifts to existing mitigation measures (i.e., backups or alternatives). The green-shaded area represents the duration of the asset’s mitigation measures. For illustration, Figure 1 shows a backup that does not support the asset’s full operations. However, if the mitigation measures support the asset’s full operations, the curve will not show any changes from the blue-shaded area. If the mitigation measure is not operational (e.g., not enough fuel to operate backup generators used to mitigate loss of electric power supply), the degradation of the asset’s operations increases. This transition is shown in the orange-shaded area. In Figure 1, the degradation in the orange-shaded area does not reach 100% degradation to illustrate that some of the asset’s operations may not require the resource considered in the curve. In case the resource is essential for all operations, the degradation will obviously reach 100% in the orange-shaded area. Some internal or external regulations may require the asset to shut down if its mitigation measures are not operational. For example, an asset may shut down if no water is available for fire suppression or sanitary purposes. In that case, all asset operations will cease. The dependency curve will therefore show a transition from the existing degradation, without using the mitigation measures, to 100% degradation. The asset is then fully shut down until the initial resource supply is restored, at which time the asset then ramps back up to full operations (i.e., 0% degradation). This last section of the dependency curve is represented by the yellow-shaded area. The duration of each section of the dependency curve varies based on the characteristics of the disruptive event and existing mitigation measures.

The Energy Infrastructure Dependency Curves Simulation Tool (simulation tool) operationalizes the concepts presented in Figure 1 in order to create customized dependency curves, which can be altered or customized for different scenarios.

3 Energy Infrastructure Dependency Curves Simulation Tool Concepts

The simulation tool has been developed to illustrate and characterize the dependency relationships existing between two subsectors (i.e., natural gas and electric power infrastructures) of the Energy Sector at the transmission level.¹ Figure 2 provides a representative schematic of the connections between the electric power and natural gas infrastructures at transmission level.

Figure 2 Interdependencies between Electric Power and Natural Gas Systems at Transmission Level (Petit et al. 2018)²

¹ The simulation tool can easily be adapted to simulate the dependency existing between all types of critical infrastructure assets. The basic concepts and questions used in the tool would remain the same; only the answers capturing the characteristics of the assets considered would vary.

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More specifically, the simulation tool characterizes how the disruption of the natural gas pipeline transmission system would affect electric power-generating capabilities. The simulation tool has been developed in Excel to provide a dynamic and easy method of characterizing the connections between two assets (i.e., natural gas-processing plant and electric power-generating plant).³ The user is able to fill out information about the two assets and their operations, including backup, shutdown, and resumption processes. Based on the responses, the tool creates two dependency curves to illustrate the disruption impacts on the assets resulting from the loss of resource supply. The simulation tool allows the user to manipulate values and view how the changes affect the dependency curves, and therefore the level of impacts on the assets. The following section presents the Questions Set used for characterizing the initiating disruptive event and the characteristics of the two assets.

³ Note that, for illustrating all components of both electric power and natural gas transportation systems, Figure 2 does not show direct connections between the natural gas-processing plant and the electric power-generating plant.

4 Questions Set

The simulation tool is designed to illustrate the direct impact of an electric power disruption on a natural gas-processing plant (Asset A) and the resulting indirect impacts on an electric power-generating plant (Asset B).

The Questions Set is subdivided into three sections:

- Initiating Event Scenario section, defining the characteristics of the initial disruptive event. The questions in this first section appear with a black title background in the simulation tool.
- Asset A section, characterizing the Asset A (i.e., natural gas-processing plant) performance and existing mitigation measures. The questions in this second section appear with a blue title background in the simulation tool.
- Asset B section, characterizing the Asset B (i.e., electric power-generating plant) performance and existing mitigation measures. The questions in this third section appear with a green title background in the simulation tool.

Response formats in the Questions Set range from times, dropdown selections, yes/no, or percentages. Guidance is provided in “helps,” which appear as question marks next to the question in the simulation tool.

The dependency curves for each asset are displayed in a locked frame above the Question Set. As questions are completed or modified, the dependency curves change dynamically to reflect the modifications. In addition, below the dependency curve is a “Clear Form” button that can be used to clear all fields in the Question Set and start over.

A complete list of the questions, as well as specific explanations and typical response values, is presented in Appendix A. The following sections provide a general overview of the questions used for generating the dependency curves.

4.1 Initiating Event Scenario (Questions 1–3)

The first questions of the simulation tool define the initiating event (i.e., loss of electric power primary supply) that will lead to the disruption of Asset A and potentially cascade to affect Asset B (Figure 3).

#	Define the Scenario
1	If there is an interruption in the electric power supplied to Asset A, what is the anticipated duration of electric supply interruption? <div> <input type="text"/> hours <input type="text"/> days <input type="text"/> weeks </div>
2	Does Asset A provide natural gas required for Asset B <u>facility operations</u> ?
3	Does Asset B provide electric power required for Asset A <u>facility operations</u> (e.g., production of key services/goods, business operations, life safety processes, maintenance activities, etc.)?

Figure 3 Initiating Event Scenario Characteristics

The first question characterizes the anticipated length of the electric supply interruption. The nature of the dependency relationship between Assets A and B is characterized in questions 2 and 3. Question 2 characterizes whether Asset B is dependent on Asset A. Question 3 characterizes whether Asset A is dependent on Asset B. If the answer to these two questions is “Yes,” Assets A and B are then interdependent.

4.2 Asset A, Natural Gas-Processing Plant

The second group of questions in the simulation tool captures the characteristics of Asset A, a natural gas-processing plant, which relies on electric power for producing pipeline-quality dry natural gas.

4.2.1 Asset A Core Operations (Question A1)

Question A1 is intended to distinguish between full facility operations and core operations, and to determine what percentage of operations performed at the facility are dedicated to the production of the key services or goods provided by the facility (Figure 4).

Asset A: Natural Gas Processing Plant	
A1	What percentage of full <u>facility operations</u> are dedicated to performing <u>core operations</u> (e.g., production of key services/goods)? <div> <input type="text"/> % </div>

Figure 4 Asset A Core Operations

For example, for a natural gas-processing plant, core operations refers specifically to the operations required to process, clean and produce natural gas to be transported by the transmission pipelines to the end users. Full facility operations would include the core operations, as well as any additional functions performed, such as maintenance, business operations, and life safety and security processes.

If the core operations account for the majority of the facility operations, this number will be high. Typical values for this field are likely to range from 90% to 99% for a natural gas-processing

plant. This means that core operations (i.e., processing and transportation of natural gas) make up the bulk of functions performed at the facility, with other functions accounting for 1–10% of full facility operations.

4.2.2 Asset A Impact without Backup (Questions A2–A3.1)

This group of questions covers operations during a disruption to the electric power supply, without accounting for backup capabilities. The three questions ask for information about the time from the power disruption until operations are affected, the level of impact, and the time to transition from full operations to this degraded level of performance (Figure 5).

Impact without Backup		
A2	If external utility provided electric power service is lost, without considering any backup, how soon would the full facility operations be impacted?	<input type="text"/> minutes <input type="text"/> hours
A3	Once external utility provided electric power service is lost, without considering any backup, what percentage of facility operations are lost or degraded?	<input type="text"/> %
A3.1	How long does it take to transition between full facility operations and this degraded performance without backup?	<input type="text"/> minutes <input type="text"/> hours

Figure 5 Asset A Impact without Backup

Responses reflect impacts on full facility operations, not only core operations. For example, if Asset A loses electric power, the asset could likely continue to operate for some time before experiencing an impact (question A2). However, once affected, the facility would transition to a degraded state of operations. The level of degradation and time to transition to that level are entered as the responses to questions A3 and A3.1.

Question A3 asks specifically what percentage of facility operations would be lost without considering backup. This would include core operations, as well as any other facility operations that require electric power. For example, if the facility loses electric power and all processing and business operations cease, except for security operations (e.g., security personnel who remain onsite), the response to this question might be 95–99%.

4.2.3 Asset A Impact with Backup (Questions A4–A8)

This question group covers operations during a disruption to the electric power supply, accounting for use of backup power sources. Here, the user can provide detailed responses to characterize Asset A’s backup generator, availability of refueling, as well as use of uninterrupted power system (UPS) and battery backup (Figure 6).

Impact with Backup	
A4	Does the facility have a backup generator(s) that can be used in case of loss of external utility provided electric power?
A4.1	How long does it take to transition operations to run on backup power? <div> <input type="text"/> minutes <input type="text"/> hours </div>
A5	How long can the generator(s) run without off-site refueling (i.e., considers onsite fuel backup)? <div> <input type="text"/> hours <input type="text"/> days </div>
A6	Is there the potential to refuel the backup?
A6.1	How many times can the backup be refueled? <input type="text"/>
A7	Does the facility have Uninterrupted Power System (UPS)/Battery backup?
A7.1	How long does the UPS/Battery backup run? <div> <input type="text"/> minutes <input type="text"/> hours </div>
A7.2	How is the UPS/Battery backup connected to the system? <input type="text"/>
A8	Once external utility provided electric power service is lost, considering all backup, what percentage of facility operations are lost or degraded? <input type="text"/> %

Figure 6 Asset A Impact with Backup

Question A5 asks for the time in which the backup can operate without receiving additional fuel from an outside source. In other words, the response here reflects only the backup capabilities with fuel typically stored onsite that would be immediately available in the event of an electric supply disruption.

Questions A6 and A6.1 refer to the potential to refuel the backup generator from an external supply source. Question 6.1 may be affected by conditions in the outside environment, and can be modified in the event of a fuel shortage or transportation disruptions affecting the ability to refuel. If the backup can be refueled indefinitely, enter 1000 for A6.1.⁴

Questions A7–A7.2 cover the use of UPS or battery backup. Availability of UPS or battery backup as well as length of use and connection to the system are therefore reflected here.

Question A8 refers to the level of degradation at the facility when backup is running. If the facility is fully operational or near fully operational, this number will be low. However, if electric power backups are used only for life safety processes or graceful shutdown of critical equipment, and most other facility operations are not supported, the percentage of facility operations lost or degraded will be high.

4.2.4 Asset A Mandated Shutdown (Questions A9–A10.1)

This series of questions covers circumstances under which internal or external regulations (e.g., environmental or health and safety requirements) may require Asset A to shut down (Figure 7).

⁴ The calculation is made in such a way that a value of 1000 refueling in many cases exceeds the extent of the initial disruption of the main electric power supply. If this not the case, the user should enter a value that exceeds the duration of the electric power outage resulting from the initiating event (question 1).

Mandated Shutdown	
A9	Are there external regulations/policies that mandate the full facility shutdown after loss of electric power service, including backups?
A10	How long after loss of electric power, including backups, would mandatory full facility shutdown occur?
	_____ hours _____ days
A10.1	How long does it take to shut down full facility operations?
	_____ minutes _____ hours _____ days

Figure 7 Asset A Mandated Shutdown

For example, if backup capabilities do not operate heating, ventilating, and air conditioning systems, employees may be sent home after a period of time; that requirement can be reflected in this section.

Question A10 reflects the time before the mandate to shut down is effective.

Question A10.1 reflects the time required to fully shut down all asset operations.

4.2.5 Asset A Resumption (Questions A11–11.3)

Once external electric power supply is restored, Asset A can return to normal operations. This group of questions covers the process and timeline for full restoration, allowing for distinctions between resumption timelines in the event that the facility is fully shut down or operating in a degraded capacity with or without core operations (Figure 8).

Resumption	
A11	Once external utility provided electric power service is restored, how long does it take to resume back to full facility operations, if:
A11.1	Facility is in full shutdown?
	_____ minutes _____ hours _____ days
A11.2	Facility is running on backup with core operations functioning?
	_____ minutes _____ hours _____ days
A11.3	Facility is running on backup, but without core operations functioning?
	_____ minutes _____ hours _____ days

Figure 8 Asset A Resumption Characteristics

Question A11.1 refers to resumption from full shutdown, which would be likely to include inspections as well as security and safety controls. This represents the maximum time required to restart (i.e., black start) Asset A full operations. Typical values for this question are likely to range from two to five days for a natural gas-processing plant if there has been no damage to the facility itself. However, some of these activities, such as inspections, may take place during the disruption, which may reduce the time to resume to full operations.

If the facility is running on backup with core operations functioning, the response to question A11.2 is likely to be similar to the response to A4.1, the time to transition to backup power.

If the facility is running on backup without core operations functioning (question A11.3), the resumption time is likely to be higher than the response to A11.2, for example, if backup power sources only facilitate shutdown or operate basic life safety functions, but do not support core operations.

4.3 Asset B – Electric Power-Generating Plant

The remaining questions in the tool capture the characteristics of Asset B, an electric power plant that relies on natural gas for generation.

4.3.1 Asset B Core Operations (Questions B1–B2)

The first group of questions addresses the type of generation and the importance of core operations (Figure 9).

Asset B: Natural Gas Fueled Power Plant	
B1	What type of power generating units are used at the facility?
B2	What percentage of full <u>facility operations</u> are dedicated to performing <u>core operations</u> (e.g., production of key services/goods)?

Figure 9 Asset B Core Operations

Question B1 asks which type of power-generating units are used at the facility; the response can be provided via a dropdown list of options. The simulation tool currently allows two types of generation: natural-gas-fired plant or dual-fuel plant.

Similar to the Asset A Questions Set, the second question attempts to distinguish between core operations (production of key good and services) and full facility operations. If core operations account for most of the operations at the facility, this number will be high. Typical values for this field range from 90% to 99% for thermal generating plants.

4.3.2 Asset B Impact without Backup (Questions B3–B4.1)

This group of questions covers operations during a disruption of the natural gas supply, without accounting for backup capabilities. The three questions ask for information about the time from the supply disruption before operations are affected, the level of impact, and the time to transition from full operations to this degraded level of performance (Figure 10).

Impact without Natural Gas Backup to Alternative Fuel		
B3	If external utility provided natural gas service is lost, without considering any backup (e.g., natural gas or alternative fuel), how soon would the full facility operations be impacted?	<input type="text"/> minutes <input type="text"/> hours
B4	Once external utility provided natural gas service is lost, without considering any backup (e.g., natural gas or alternative fuel), what percentage of facility operations are lost or degraded?	<input type="text"/> %
B4.1	How long does it take to transition between full facility operations and this degraded performance without backup (e.g., natural gas or alternative fuel)?	<input type="text"/> minutes <input type="text"/> hours

Figure 10 Asset B Impact without Backup

Responses reflect impacts on full facility operations, not only core operations.

Question B3 illustrates the delay from the time of the disruption until operations at the facility are affected.

Question B4 asks about percentage of operations affected once the natural gas supply is lost, without accounting for backup or alternative fuels. The response to this question is likely to be complementary to the response to question B2, and should characterize the percentage of operations at the facility that are supported primarily through use of natural gas. Note that if natural gas is used solely to support core operations, the response to B4 should match the response to B2. However, if natural gas is also used for noncore functions, such as onsite heating or food preparation, the response to B4 will be greater than the response to B2.

4.3.3 Asset B Impact with Backup (Questions B5–B8)

This group of questions covers operations during a disruption of the natural gas supply, accounting for the use of backup but not an alternative fuel supply (Figure 11).

Impact with Natural Gas Backup	
B5	Does the facility have a backup natural gas supply (e.g., onsite storage) that can be used in case of loss of external utility provided natural gas?
B5.1	How long does it take to transition operations to run on backup natural gas supply? minutes hours
B6	How long can operations run on backup natural gas without resupply? hours days
B7	Is there the potential to resupply the backup natural gas ?
B7.1	How many times can the backup natural gas be resupplied?
B8	Once external utility provided natural gas service is lost, considering all backup natural gas supplies, what percentage of facility operations are lost or degraded? %

Figure 11 Asset B Impact with Backup

Here, backup specifically refers to an alternative natural gas supply or natural gas stored onsite that can be accessed quickly in the event of a disruption of the main supply. These questions offer the opportunity to provide detailed responses to characterize the facility’s backup and potential to resupply.

Question B6 asks specifically how long the backup can operate without receiving additional supply from an outside source. In other words, the response here should reflect only the backup capabilities typically stored onsite or that would otherwise be immediately available in the event of a disruption. Resupply would involve obtaining additional natural gas from an outside source.

Question B8 refers to the level of degradation at the facility when backup supplies are used. If the facility is fully operational or near fully operational, this number will be low. Similar to the response to question B4, this response should take into account core and noncore uses of natural gas onsite. For example, if the backup only supports core operations, but 5% of operations account for noncore uses of natural gas (e.g., onsite facility heating), then the response to B8 would be 5%.

4.3.4 Asset B Impact with Alternative Fuel (Questions B9–B12)

This question group covers alternative or secondary fuel sources (such as petroleum) that can be used to perform core operations, separate from any backup supplies of the primary fuel type (Figure 12).

Impact with Alternative Fuel	
B9	Is there an alternative fuel source (e.g., petroleum, oil, etc.) available for facility core operations?
B9.1	What alternative type of fuel is used?
B9.2	How long does it take to transition operations to run on an alternative fuel source?
	minutes
	hours
	days
B10	How long can operations run on an alternative fuel source without resupply?
	hours
	days
B11	Is there the potential to resupply the alternative fuel source?
B11.1	How many times can the alternative fuel source be resupplied?
B12	Once external utility provided natural gas service is lost, considering all alternative fuel supplies, what percentage of facility operations are lost or degraded?
	%

Figure 12 Asset B Impact with Alternative Fuel

Questions include the type of fuel used, which can be selected from a dropdown menu, the transition to and from operation using the alternative fuel, resupply, and level of degradation. Using alternative fuel is a possibility for a dual-fuel generating plant but is not an option for a natural-gas-fired generating plant that is dependent on natural gas as a primary fuel source.

Questions B9 to B9.2 characterize the possibility of using alternative fuels. Question B9.2 refers to the time required to transition operations to run on the alternative fuel source. Typical responses range from 1 minute to 12 hours depending on the number of generating units transitioned to alternative fuels.

Question B10 asks how long operations can run on the alternative fuel source without resupplying. This would include any onsite storage of alternative fuel.

Questions B11 and B11.1 characterize refueling options. The response to question B11.1 may be affected by conditions in the outside environment, and can be modified in the event of a fuel shortage or transportation disruptions affecting the ability to refuel. If the alternative fuel can be resupplied indefinitely, enter 1000 for B12.⁵

Question B12 refers to the level of degradation at the facility when alternative fuels are used. If the facility is fully operational or near fully operational, this number will be low. Similar to the responses to questions B4 and B8, this response should take into account core and noncore uses of natural gas onsite. For example, if the alternative fuel only supports core operations, but 5% of operations account for noncore uses of natural gas (e.g., onsite asset heating), then the response to B12 would be 5%.

⁵ The calculation is made in such a way that a value of 1000 refueling in many cases exceeds the extent of the initial disruption of the main electric power supply (i.e., initiating event). If this not the case, the user should enter a value that exceeds the duration of the electric power outage resulting from the initiating event (Figure 13

4.3.5 Asset B Mandated Shutdown (Questions B13–B15)

This series of questions covers circumstances under which internal or external regulations (e.g., environmental or health and safety requirements) may require Asset B to shut down (Figure 13).

Mandated Shutdown		
B13	Are there external regulations/policies that mandate the full facility shutdown after loss of natural gas service, including natural gas backup and alternative fuel supplies?	<input type="text"/>
B13.1	How long after loss of natural gas, including natural gas backup and alternative fuel supplies, would mandatory full facility shutdown occur?	<input type="text"/> hours <input type="text"/> days
B14	Are there external regulations/policies that mandate the full facility shutdown if running on an alternative fuel source?	<input type="text"/>
B14.1	How long after changing over to an alternative fuel source would mandatory full facility shutdown occur?	<input type="text"/> hours <input type="text"/> days
B15	How long does it take to shut down full facility operations?	<input type="text"/> minutes <input type="text"/> hours <input type="text"/> days

Figure 13 Asset B Mandated Shutdown

For example, if backups are exhausted and core operations are not supported, decisions could be made to cease all operations; that requirement can be reflected in this section.

Questions B13 and B14 reflect the existence of external or internal obligations to cease operations if the supplies of natural gas or alternative fuel are interrupted.

Questions B13.1 and B14.1 reflect the time before the mandate to shut down is effective.

Question B15 reflects the time required to fully shut down all asset operations.

4.3.6 Asset B Resumption (Questions B16–B16.5)

Once the natural gas supply service is restored, the facility can return to full operations. This set of questions covers the process and timeline for full restoration, allowing for distinctions between resumption timelines in the event that the facility is fully shut down, running on backup with or without core operations, and running on alternative fuel at full or partial capacity (Figure 14).

Resumption		
B16	Once external utility provided natural gas service is restored, how long does it take to resume back to full facility operations, if:	
B16.1	Facility is in full shutdown?	<div><div></div>minutes</div> <div><div></div>hours</div> <div><div></div>days</div>
B16.2	Facility is running on natural gas backup with core operations functioning?	<div><div></div>minutes</div> <div><div></div>hours</div> <div><div></div>days</div>
B16.3	Facility is running on natural gas backup, but without core operations functioning?	<div><div></div>minutes</div> <div><div></div>hours</div> <div><div></div>days</div>
B16.4	Facility is running on alternative fuel with core operations functioning?	<div><div></div>minutes</div> <div><div></div>hours</div> <div><div></div>days</div>
B16.5	Facility is running on alternative fuel, but without core operations functioning?	<div><div></div>minutes</div> <div><div></div>hours</div> <div><div></div>days</div>

Figure 14 Asset B Resumption

For example, in the event that the initial disruption is not anticipated to extend beyond one or two days and the facility requires 12 hours to switch to an alternative fuel and back to the primary fuel, the decision may be made to switch only some of the units, in order to speed up resumption times once service is restored.

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5 Demonstration Scenarios

Three infrastructure dependency scenarios have been developed to demonstrate the use of the simulation tool and characterize the connections existing between natural gas infrastructure assets and electric power generation assets (Table 1).

Table 1 Dependency of Asset B on Natural Gas Supplied by Asset A

Asset A	Asset B
Natural Gas-Processing plant^a Immediate impact Backup generator able to operate during 24 hours without refueling Possibility of refuel twice UPS and battery to accommodate switch to backup generator	Scenario 1 – Natural-Gas-Fired Generating Plant Immediate Impact No natural gas supply backup
	Scenario 2 – Dual-Fuel Generating Plant Immediate Impact No natural gas supply backup Possible use of alternative fuel
	Scenario 3 – Dual-Fuel Generating Plant Immediate Impact Natural gas supply backup ^b Possible use of alternative fuel

^a The characteristics of Asset A remain the same for all three scenarios; only the characteristics of Asset B change depending on the scenario.

^b In general, there is no natural gas backup implemented at the electric power-generating plant. In scenario 3, natural gas supply backup such as use of LNG (Liquefied Natural Gas) is selected to illustrate its effect on the dependency curves.

Asset A is a natural gas-processing plant that experiences a disruption of electric power supply resulting from a winter storms event. Asset B is an electric power-generating plant that is dependent upon the natural gas supplied by Asset A.

The following sections present the information that must be entered in the simulation tool for these three scenarios and discuss the resulting dependency curves.

The three scenarios presented, and the characteristics of Assets A and B, are illustrative and do not depict real cases.

5.1 Initiating event

The initiating event is the same for all three scenarios. A series of severe winter storms bring freezing rain and snow, high winds, and subzero temperatures, resulting in extensive damage to the electric grid transmission system. Numerous lines are damaged, and repairs are hindered because of dangerous weather and transportation conditions. This results in an electric power outage that lasts two weeks.

Figure 15 shows the questions and corresponding answers characterizing the initiating event.

#	Define the Scenario	
1	If there is an interruption in the electric power supplied to Asset A, what is the anticipated duration of electric supply interruption?	<input type="text"/> hours <input type="text"/> days <input checked="" type="text"/> 2 weeks
2	Does Asset A provide natural gas required for Asset B <u>facility operations</u> ?	Yes
3	Does Asset B provide electric power required for Asset A <u>facility operations</u> (e.g., production of key services/goods, business operations, life safety processes, maintenance activities, etc.)?	No

Figure 15 Initiating Event Characteristics

5.2 Asset A Characteristics

The characteristics of Asset A remain the same for all three scenarios.

5.2.1 Asset A Core Operations

The majority of Asset A’s operations (95%) are dedicated to the transportation of natural gas (Figure 16).

Asset A: Natural Gas Processing Plant	
A1	What percentage of full <u>facility operations</u> are dedicated to performing <u>core operations</u> (e.g., production of key services/goods)? <input checked="" type="text"/> 95 %

Figure 16 Asset A Core Operations

5.2.2 Asset A Impact without Backup

Asset A is immediately affected by the loss of electric power supply resulting from the winter storms event. Most of the facility operations (i.e., core operations and most of the supporting operations) use electric power and would be affected by the electric power outage. If no backup is used, the transition would be immediate between full facility operations and degraded performance. Figure 17 shows the questions and answers characterizing the impact of the loss of electric power supply on Asset A’s operations if no backup is used.

Impact without Backup		
A2	If external utility provided electric power service is lost, without considering any backup, how soon would the full facility operations be impacted?	0 minutes hours
A3	Once external utility provided electric power service is lost, without considering any backup, what percentage of facility operations are lost or degraded?	95 %
A3.1	How long does it take to transition between full facility operations and this degraded performance without backup?	0 minutes hours

Figure 17 Asset A Impact without Backup

5.2.3 Asset A Impact with Backup

Asset A has both UPS batteries and backup diesel generators that can be used in case of loss of the main electric power supply. These backups last 24 hours without refueling and support 90% of Asset A’s operations. It is considered that refueling of the generators will be possible only twice before roads are made impassable due to the succession of winter storms. Figure 18 shows the questions and answers characterizing Asset A’s backups and resulting impact on operations.

Impact with Backup		
A4	Does the facility have a backup generator(s) that can be used in case of loss of external utility provided electric power?	Yes
A4.1	How long does it take to transition operations to run on backup power?	15 minutes hours
A5	How long can the generator(s) run without off-site refueling (i.e., considers onsite fuel backup)?	24 hours days
A6	Is there the potential to refuel the backup?	Yes
A6.1	How many times can the backup be refueled?	2
A7	Does the facility have Uninterrupted Power System (UPS)/Battery backup?	Yes
A7.1	How long does the UPS/Battery backup run?	30 minutes hours
A7.2	How is the UPS/Battery backup connected to the system?	To accommodate switch from exte
A8	Once external utility provided electric power service is lost, considering all backup, what percentage of facility operations are lost or degraded?	5 %

Figure 18 Asset A Impact with Backup

5.2.4 Asset A Mandated Shutdown

When Asset A loses all electric power sources (i.e., main and backup supplies), all operations would require ceasing after 2 hours. Figure 19 shows the questions and answers characterizing Asset A mandated shutdown.

Mandated Shutdown	
A9	Are there external regulations/policies that mandate the full facility shutdown after loss of electric power service, including backups? Yes
A10	How long after loss of electric power, including backups, would mandatory full facility shutdown occur? 2 hours days
A10.1	How long does it take to shut down full facility operations? minutes 1 hours days

Figure 19 Asset A Mandated Shutdown

5.2.5 Asset A Resumption

The time required for resumption of Asset A operations after restoration of the electric power main supply varies depending on the state of operation of Asset A. The facility can resume its operations in 15 minutes if it operates on backups to a maximum of four days if the facility is on full shutdown. It would take about 2 days if the facility is running on backup without core operations functioning. Figure 20 shows the questions and answers characterizing the times needed for Asset A resumption.

Resumption	
A11	Once external utility provided electric power service is restored, how long does it take to resume back to full facility operations, if:
A11.1	Facility is in full shutdown? minutes hours 4 days
A11.2	Facility is running on backup with core operations functioning? 15 minutes hours days
A11.3	Facility is running on backup, but without core operations functioning? minutes hours 2 days

Figure 20 Asset A Resumption

The responses for all Asset A questions remain the same for all three scenarios, but Asset B is altered to illustrate different backup and alternative fuel postures and resulting dependency curves. The following sections present the characteristics of Asset B for the three scenarios.

5.3 Scenario 1

In the first scenario, Asset B is a natural-gas-fired generating plant. Appendix B presents an overview of Scenario 1 in the simulation tool. A total of 95% of Asset B’s operations is dedicated to the generation of electric power (Figure 21).

Asset B: Natural Gas Fueled Power Plant	
B1	<div>What type of power generating units are used at the facility?</div> <div>Natural gas fired generating plant</div>
B2	<div>What percentage of full facility operations are dedicated to performing core operations (e.g., production of key services/goods)?</div> <div>95 %</div>

Figure 21 Scenario 1 – Asset B Core Operations

5.3.1 Asset B Impact without Backup

Asset B is affected by the loss of natural gas supplied by Asset A after 1 hour. Most of the facility operations (95%) use natural gas and would be affected by the disruption of Asset A supply. If no backup is used, the transition between full facility operations and degraded performance would take about 30 minutes. Figure 22 shows the questions and answers characterizing the impact of the loss of natural gas on Asset B’s operations if no backup is used.

Impact without Natural Gas Backup or Alternative Fuel	
B3	<div>If external utility provided natural gas service is lost, without considering any backup (e.g., natural gas or alternative fuel), how soon would the full facility operations be impacted?</div> <div> <div>minutes</div> <div>1 hours</div> </div>
B4	<div>Once external utility provided natural gas service is lost, without considering any backup (e.g., natural gas or alternative fuel), what percentage of facility operations are lost or degraded?</div> <div>95 %</div>
B4.1	<div>How long does it take to transition between full facility operations and this degraded performance without backup (e.g., natural gas or alternative fuel)?</div> <div> <div>30 minutes</div> <div>hours</div> </div>

Figure 22 Scenario 1 – Asset B Impact without Backup

5.3.2 Asset B Impact with Backup

Asset B does not have any backup to mitigate the loss of natural gas supplied by Asset A. Figure 23 shows the questions and answers characterizing Asset B’s backups and resulting impact on operations.

Impact with Natural Gas Backup		
B5	Does the facility have a backup natural gas supply (e.g., onsite storage) that can be used in case of loss of external utility provided natural gas?	No
B5.1	How long does it take to transition operations to run on backup natural gas supply?	minutes hours
B6	How long can operations run on backup natural gas without resupply?	hours days
B7	Is there the potential to resupply the backup natural gas ?	
B7.1	How many times can the backup natural gas be resupplied?	
B8	Once external utility provided natural gas service is lost, considering all backup natural gas supplies, what percentage of facility operations are lost or degraded?	%

Figure 23 Scenario 1 – Asset B Impact with Backup

5.3.3 Asset B Impact with Alternative Fuel

Asset B is a natural-gas-fired generating plant and can be fueled only with natural gas. Therefore, the questions characterizing the impact with an alternative fuel do not apply and do not need to be answered (Figure 24).

Impact with Alternative Fuel		
B9	Is there an alternative fuel source (e.g., petroleum, oil, etc.) available for facility core operations?	
B9.1	What alternative type of fuel is used?	
B9.2	How long does it take to transition operations to run on an alternative fuel source?	minutes hours days
B10	How long can operations run on an alternative fuel source without resupply?	hours days
B11	Is there the potential to resupply the alternative fuel source?	
B11.1	How many times can the alternative fuel source be resupplied?	
B12	Once external utility provided natural gas service is lost, considering all alternative fuel supplies, what percentage of facility operations are lost or degraded?	%

Figure 24 Scenario 1 – Asset B Impact with Alternative Fuel

5.3.4 Asset B Mandated Shutdown

When Asset B loses the main natural gas source, all operations would require ceasing after 8 hours. Four hours are needed to shut down full facility operations. Figure 25 shows the questions and answers characterizing Asset B mandated shutdown.

Mandated Shutdown		
B13	Are there external regulations/policies that mandate the full facility shutdown after loss of natural gas service, including natural gas backup and alternative fuel supplies?	Yes
B13.1	How long after loss of natural gas, including natural gas backup and alternative fuel supplies, would mandatory full facility shutdown occur?	8 hours days
B14	Are there external regulations/policies that mandate the full facility shutdown if running on an alternative fuel source?	
B14.1	How long after changing over to an alternative fuel source would mandatory full facility shutdown occur?	hours days
B15	How long does it take to shut down full facility operations?	minutes 4 hours days

Figure 25 Scenario 1 – Asset B Mandated Shutdown

5.3.5 Asset B Resumption

The time required for the resumption of Asset B operations after restoration of the natural gas main supply varies depending on the state of operation of Asset B. The facility can resume its operations in 15 minutes if it operates on backups to a maximum of four days if the asset is on full shutdown. Figure 26 shows the questions and answers characterizing times needed for Asset B resumption.

Resumption		
B16	Once external utility provided natural gas service is restored, how long does it take to resume back to full facility operations, if:	
B16.1	Facility is in full shutdown?	minutes hours 4 days
B16.2	Facility is running on natural gas backup with core operations functioning?	15 minutes hours days
B16.3	Facility is running on natural gas backup, but without core operations functioning?	minutes 8 hours days
B16.4	Facility is running on alternative fuel with core operations functioning?	minutes hours days
B16.5	Facility is running on alternative fuel, but without core operations functioning?	minutes hours days

Figure 26 Scenario 1 – Asset B Resumption

5.3.6 Scenario 1 Output

Scenario 1 illustrates maximum impact for Asset B. In this scenario, Asset B is a natural-gas-fueled power plant, which is strongly dependent on Asset A for its utility-provided natural gas supply. Asset A does not have a backup to mitigate the loss of natural gas supply. As a result, any disruption of Asset A’s operations (e.g., loss of electricity resulting from downed power lines) significantly affects Asset B’s operations. Figure 27 shows the dependency curves for Scenario 1 for both Assets A and B as they appear above the question set in the simulation tool.

Figure 27 Scenario 1 – Simulation Tool Output

Following an electric power disruption, Asset A is able to temporarily operate at reduced capacity using backup generators. However, it is forced to shut down once backup capacity is depleted. When Asset A shuts down, supply of natural gas ceases and Asset B becomes affected. With no backup available, the loss of utility natural gas service from Asset A results in the almost immediate shutdown of Asset B. Once backup capabilities cease, mandatory shutdown occurs until the main resource supplies are restored. When electric power supply is restored at the end of the two-week outage, Asset A is able to ramp back up to normal full operations, accounting for the time needed to conduct safety inspections and black start the operations. Once Asset A is able to resume the supply of natural gas in transporting pipelines, Asset B can begin its gradual return to full operations.

In this scenario, Asset A mitigation measures are not sufficient to prevent stopping the transportation of natural gas by Asset A or to avoid a full shutdown of Asset B. Figure 28 presents the dependency curves with the major events characterizing Scenario 1.

Figure 28 Scenario 1 – Simulation Tool Annotated Output

5.4 Scenario 2

In this second scenario, Asset B is a dual-fuel generating plant with no backup storage or alternative supply for natural gas, but it has the ability to use residual fuel oil as an alternative fuel for three days without refueling. Appendix C presents an overview of Scenario 2 in the simulation tool. Similar to Scenario 1, 95% of Asset B’s operations are dedicated to the generation of electric power (Figure 29).

Asset B: Dual Fuel Power Plant		
B1	What type of power generating units are used at the facility?	Dual fueled generating plant
B2	What percentage of full <u>facility operations</u> are dedicated to performing <u>core operations</u> (e.g., production of key services/goods)?	95 %

Figure 29 Scenario 2 – Asset B Core Operations

5.4.1 Asset B Impact without Backup

The impact on Asset B of the loss of natural gas supply without considering existing backups is the same as that for Scenario 1 (Figure 30).

Impact without Natural Gas Backup or Alternative Fuel		
B3	If external utility provided natural gas service is lost, without considering any backup (e.g., natural gas or alternative fuel), how soon would the full facility operations be impacted?	_____ minutes _____ 1 hours
B4	Once external utility provided natural gas service is lost, without considering any backup (e.g., natural gas or alternative fuel), what percentage of facility operations are lost or degraded?	_____ 95 %
B4.1	How long does it take to transition between full facility operations and this degraded performance without backup (e.g., natural gas or alternative fuel)?	_____ 30 minutes _____ hours

Figure 30 Scenario 2 – Asset B Impact without Backup

5.4.2 Asset B Impact with Backup

Similar to Scenario 1, Asset B in Scenario 2 does not have any backup to mitigate the loss of natural gas supplied by Asset A (Figure 31).

Impact with Natural Gas Backup		
B5	Does the facility have a backup natural gas supply (e.g., onsite storage) that can be used in case of loss of external utility provided natural gas?	_____ No
B5.1	How long does it take to transition operations to run on backup natural gas supply?	_____ minutes _____ hours
B6	How long can operations run on backup natural gas without resupply?	_____ hours _____ days
B7	Is there the potential to resupply the backup natural gas ?	_____
B7.1	How many times can the backup natural gas be resupplied?	_____
B8	Once external utility provided natural gas service is lost, considering all backup natural gas supplies, what percentage of facility operations are lost or degraded?	_____ %

Figure 31 Scenario 2 – Asset B Impact with Backup

5.4.3 Asset B Impact with Alternative Fuel

Asset B can use residual fuel oil as alternative fuel. Twelve hours are needed to transition to an alternative fuel (i.e., time needed to modify equipment to burn the new fuel). Asset B can operate one week on alternative fuel without being resupplied and support 95% of whole facility operations. It is considered that refueling will not be possible because of the succession of winter storms. Figure 32 shows the questions and answers characterizing the impacts on Asset B’s operations when the use of alternative fuel is considered.

Impact with Alternative Fuel		
B9	Is there an alternative fuel source (e.g., petroleum, oil, etc.) available for facility core operations?	Yes
B9.1	What alternative type of fuel is used?	oil
B9.2	How long does it take to transition operations to run on an alternative fuel source?	minutes 12 hours days
B10	How long can operations run on an alternative fuel source without resupply?	hours 7 days
B11	Is there the potential to resupply the alternative fuel source?	No
B11.1	How many times can the alternative fuel source be resupplied?	
B12	Once external utility provided natural gas service is lost, considering all alternative fuel supplies, what percentage of facility operations are lost or degraded?	5 %

Figure 32 Scenario 2 – Asset B Impact with Alternative Fuel

5.4.4 Asset B Mandated Shutdown

Similar to Scenario 1, when Asset B loses the main natural gas source, all operations would require ceasing after 8 hours. Four hours are needed to shut down full facility operations. There is no regulation that mandates a shutdown in case of loss of alternative fuel (i.e., oil) supply. Figure 33 shows the questions and answers characterizing Asset B’s mandated shutdown.

Mandated Shutdown		
B13	Are there external regulations/policies that mandate the full facility shutdown after loss of natural gas service, including natural gas backup and alternative fuel supplies?	Yes
B13.1	How long after loss of natural gas, including natural gas backup and alternative fuel supplies, would mandatory full facility shutdown occur?	8 hours days
B14	Are there external regulations/policies that mandate the full facility shutdown if running on an alternative fuel source?	No
B14.1	How long after changing over to an alternative fuel source would mandatory full facility shutdown occur?	hours days
B15	How long does it take to shut down full facility operations?	minutes 4 hours days

Figure 33 Scenario 2 – Asset B Mandated Shutdown

5.4.5 Asset B Resumption

The resumption times are the same as those for Scenario 1 when Asset B is in full shutdown or running on natural gas backup. Resumption times vary between one and three days when Asset B is running on alternative fuel. Figure 34 shows the questions and answers characterizing the times needed for Asset B resumption.

Resumption		
B16	Once external utility provided natural gas service is restored, how long does it take to resume back to full facility operations, if:	
B16.1	Facility is in full shutdown?	<input type="text"/> minutes <input type="text"/> hours <input type="text"/> 4 days
B16.2	Facility is running on natural gas backup with core operations functioning?	<input type="text"/> minutes <input type="text"/> hours <input type="text"/> days
B16.3	Facility is running on natural gas backup, but without core operations functioning?	<input type="text"/> minutes <input type="text"/> hours <input type="text"/> days
B16.4	Facility is running on alternative fuel with core operations functioning?	<input type="text"/> minutes <input type="text"/> hours <input type="text"/> 1 days
B16.5	Facility is running on alternative fuel, but without core operations functioning?	<input type="text"/> minutes <input type="text"/> hours <input type="text"/> 3 days

Figure 34 Scenario 2 – Asset B Resumption

5.4.6 Scenario 2 Output

Scenario 2 illustrates slightly mitigated impacts on Asset B, in comparison with Scenario 1. The main difference between these two scenarios is that Asset B is now a dual-fuel power plant, which uses natural gas as its primary fuel, but has the capability to switch its operations over to an alternative fuel source (i.e., residual fuel oil). Thus, Asset B is able to maintain the majority of its operations for a set time while running on this alternative fuel supply. The dependency curve for Asset A remains the same as for Scenario 1. The dependency curves for Asset B show a shorter interruption time. Figure 35 shows the dependency curves for Scenario 2 for both assets A and B as they appear above the Question Set in the simulation tool.

Figure 35 Scenario 2 – Simulation Tool Output

When using the alternative fuel, Asset B’s core operations (e.g., running the generating units) are supported. Some supportive operations go offline, which leads to a slightly decreased performance level. The use of alternative fuel also requires a changeover of the burner equipment in the generating units (i.e., so they are able to burn oil instead of natural gas), which takes some additional time. As a result, there is an immediate decrease of performance until enough generating units are transitioned to the alternative fuel and able to produce sufficient power again. If Asset A is still offline when Asset B’s alternative fuel is spent, Asset B will shut down. Once main and alternative resources supply ceases at both assets, mandatory shutdown occurs until main resource supplies are restored. The shutdown procedures and resumption to full normal operations are the same as those in Scenario 1; therefore, the last section of the dependency curves is the same as for Scenario 1.

In this scenario, Asset B’s ability to run nearly all its operations on alternative fuel provides an increased resilience. Without resupply of alternative fuel, Asset B eventually shuts down. Figure 36 presents the dependency curves with the major events characterizing Scenario 2.

Figure 36 Scenario 2 – Simulation Tool Annotated Output

5.5 Scenario 3

For the third scenario, Asset B is a dual-fuel generating plant with two days of natural gas backup and the ability to operate on residual fuel oil as an alternative fuel for three days. Appendix D presents an overview of Scenario 3 in the simulation tool. Similar to the two other scenarios, 95% of Asset B’s operations are dedicated to the generation of electric power (Figure 37).

Asset B: Dual Fuel Power Plant		
B1	What type of power generating units are used at the facility?	Dual fueled generating plant
B2	What percentage of full <u>facility operations</u> are dedicated to performing <u>core operations</u> (e.g., production of key services/goods)?	95 %

Figure 37 Scenario 3 – Asset B Core Operations

5.5.1 Asset B Impact without Backup

The impact on Asset B of the loss of natural gas supply without considering existing backups is the same as for Scenarios 1 and 2 (Figure 38).

Impact without Natural Gas Backup or Alternative Fuel		
B3	If external utility provided natural gas service is lost, without considering any backup (e.g., natural gas or alternative fuel), how soon would the full facility operations be impacted?	_____ minutes 1 hours
B4	Once external utility provided natural gas service is lost, without considering any backup (e.g., natural gas or alternative fuel), what percentage of facility operations are lost or degraded?	95 %
B4.1	How long does it take to transition between full facility operations and this degraded performance without backup (e.g., natural gas or alternative fuel)?	30 minutes _____ hours

Figure 38 Scenario 3 – Asset B Impact without Backup

5.5.2 Asset B Impact with Backup

Unlike scenario 2, in scenario 3 Asset B has a backup that can be used in case of loss of the main natural gas supply.⁶ It takes 15 minutes to transition operations to run on natural gas backup. This backup lasts two days without refueling and supports 95% of all facility operations. Figure 39 shows the questions and answers characterizing the impacts on Asset B’s operations when natural gas backup is considered.

⁶ In general, there is no backup in case of loss of the natural gas supply for the electric power-generating plant. Elements of Scenario 3 defining the natural gas backup are used only for illustration purposes.

Impact with Natural Gas Backup		
B5	Does the facility have a backup natural gas supply (e.g., onsite storage) that can be used in case of loss of external utility provided natural gas?	Yes
B5.1	How long does it take to transition operations to run on backup natural gas supply?	15 minutes hours
B6	How long can operations run on backup natural gas without resupply?	hours 2 days
B7	Is there the potential to resupply the backup natural gas ?	No
B7.1	How many times can the backup natural gas be resupplied?	
B8	Once external utility provided natural gas service is lost, considering all backup natural gas supplies, what percentage of facility operations are lost or degraded?	5 %

Figure 39 Scenario 3 – Asset B Impact with Backup

5.5.3 Asset B Impact with Alternative Fuel

Asset B’s capability to use alternative fuel is the same as that for Scenario 2. Twelve hours are needed to transition to an alternative fuel. Asset B can operate one week on alternative fuel without being resupplied and support 95% of whole facility operations. Refueling is considered not to be possible because of the succession of winter storms. Figure 40 shows the questions and answers characterizing the impacts on Asset B’s operations when the use of alternative fuel is considered.

Impact with Alternative Fuel		
B9	Is there an alternative fuel source (e.g., petroleum, oil, etc.) available for facility core operations?	Yes
B9.1	What alternative type of fuel is used?	oil
B9.2	How long does it take to transition operations to run on an alternative fuel source?	minutes 12 hours days
B10	How long can operations run on an alternative fuel source without resupply?	hours 7 days
B11	Is there the potential to resupply the alternative fuel source?	No
B11.1	How many times can the alternative fuel source be resupplied?	
B12	Once external utility provided natural gas service is lost, considering all alternative fuel supplies, what percentage of facility operations are lost or degraded?	5 %

Figure 40 Scenario 3 – Asset B Impact with Alternative Fuel

5.5.4 Asset B Mandated Shutdown

The mandated shutdown characteristics are the same as those for Scenario 2. When Asset B loses the main natural gas source, all operations would require ceasing after 8 hours. Four hours are needed to shut down full facility operations. There is no regulation that mandates a shutdown in case of loss of alternative fuel supply. Figure 41 shows the questions and answers characterizing Asset B’s mandated shutdown.

Mandated Shutdown		
B13	Are there external regulations/policies that mandate the full facility shutdown after loss of natural gas service, including natural gas backup and alternative fuel supplies?	Yes
B13.1	How long after loss of natural gas, including natural gas backup and alternative fuel supplies, would mandatory full facility shutdown occur?	8 hours days
B14	Are there external regulations/policies that mandate the full facility shutdown if running on an alternative fuel source?	No
B14.1	How long after changing over to an alternative fuel source would mandatory full facility shutdown occur?	hours days
B15	How long does it take to shut down full facility operations?	minutes 4 hours days

Figure 41 Scenario 3 – Asset B Mandated Shutdown

5.5.5 Asset B Resumption

The resumption times are similar to those for Scenario 2. The time to resume full facility operations is between 15 minutes and four days depending on the state of facility operations. Figure 42 shows the questions and answers characterizing times needed for Asset B resumption.

Resumption		
B16	Once external utility provided natural gas service is restored, how long does it take to resume back to full facility operations, if:	
B16.1	Facility is in full shutdown?	<input type="text"/> minutes <input type="text"/> hours <input type="text"/> 4 days
B16.2	Facility is running on natural gas backup with core operations functioning?	<input type="text"/> 15 minutes <input type="text"/> hours <input type="text"/> days
B16.3	Facility is running on natural gas backup, but without core operations functioning?	<input type="text"/> minutes <input type="text"/> 8 hours <input type="text"/> days
B16.4	Facility is running on alternative fuel with core operations functioning?	<input type="text"/> minutes <input type="text"/> hours <input type="text"/> 1 days
B16.5	Facility is running on alternative fuel, but without core operations functioning?	<input type="text"/> minutes <input type="text"/> hours <input type="text"/> 3 days

Figure 42 Scenario 3 – Asset B Resumption

5.5.6 Scenario 3 Output

Scenario 3 represents conditions that further mitigate the impacts on Asset B, in comparison with both Scenarios 1 and 2. In this scenario, Asset B is a dual-fuel power plant, similar to Scenario 2; however, it now has both a natural gas backup capability (e.g., natural gas storage) and the ability to use alternative fuel. The increased adaptive capacity from its own natural gas backup allows Asset B to maintain the majority of its operations for a longer period of time after the loss of natural gas supplied by Asset A. The dependency curve for Asset A is once again the same as in the two previous scenarios. The dependency curves for Asset B show a greater resilience capability (i.e., greater level of performance). Figure 43 shows the dependency curves for Scenario 3 for both Assets A and B as they appear above the question set in the simulation tool.

Figure 43 Scenario 3 – Simulation Tool Output

With its own natural gas backup supply, Asset B is able to immediately transition its operations without any downtime after Asset A ceases operations. As a result, Asset B is able to maintain its operations with only a slight drop in performance (accounting for use of backup to support all core operations but not all supportive operations). The natural gas backup also allows a seamless transition to the alternative fuel, such that no change in performance is observed. If Asset A is still offline when Asset B’s natural gas backup and alternative fuel supplies are exhausted, Asset B will shut down, although its duration offline is reduced. Once backups and alternatives cease functioning at both assets, mandatory shutdown occurs. The shutdown procedures and resumption to full normal operations are the same as those in Scenarios 1 and 2; therefore, the last section of the dependency curves is the same for all three scenarios. When the main supply sources are restored, the two assets resume their full operations.

In this scenario, natural gas backup supply allows Asset B to seamlessly transition its operations to run on alternative fuel, eliminating downtime and increasing resilience. Without resupply of alternative fuel, Asset B eventually shuts down. Figure 44 presents the dependency curves with the major events characterizing Scenario 3.

Figure 44 Scenario 3 – Simulation Tool Annotated Output

6 Conclusion

Critical infrastructure interdependencies are complex elements to consider. The Energy Infrastructure Dependency Curves Simulation Tool provides an interactive means to display and analyze the complexities of infrastructure dependencies. The tool is currently designed to allow simulating dependency relationships between a natural gas-processing plant and an electric power-generating plant. Three scenarios were presented to demonstrate the use of the simulation tool and illustrate how dependency characteristics affect the performance of the processing plant and the generating plant. The simulation tool could be enhanced to simulate infrastructure interdependency among other energy sector assets and adapted to understand existing relationships among other critical infrastructure sectors.

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7 References

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Appendix A – Question Set Quick Reference

Number	Question	Additional Description	Response Format/Range	Typical Values
Scenario				
1	If there is an interruption in the electric power supplied to Asset A, what is the anticipated duration of electric supply interruption?	Enter the anticipated duration of the disruption. This value can be changed as the event evolves.	Time hours/days/weeks	
2	Does Asset A provide natural gas required for Asset B <i>facility operations</i> ?	Facility operations include both core operations (production of key services and resources) and supportive operations (e.g., maintenance activities, business operations, life safety processes). For example, the core operations for a natural gas compressor station relate to the movement of natural gas.	Dropdown choice yes/no	
3	Does Asset B provide electric power required for Asset A operations (e.g., production of key services/goods, business operations, life safety processes, maintenance activities)?	For example, the core operations for a generating plant relate to the production/generation of electric power.	Dropdown choice yes/no	

Number	Question	Additional Description	Response Format/Range	Typical Values	
ASSET A: Natural Gas-Processing Plant					
Asset A Core Operations					
A1	What percentage of full <i>facility operations</i> are dedicated to performing <i>core operations</i> (e.g., production of key services/goods)?	This question is intended to distinguish between full facility operations and core operations, and to determine what percentage of operations performed at the facility are dedicated to the production of the key services or goods provided by the facility.	Percentage 0–100	90–99%	
Asset A Impact without Backup					
A2	If external utility-provided electric power service is lost, without considering any backup, how soon would the full facility operations be impacted?	This question captures the time length between the occurrence of the disruption event until the facility is affected (i.e., how long the asset will continue to operate before being affected?).	Time minutes/hours	0 minute	
A3	Once external utility-provided electric power service is lost, without considering any backup, what percentage of asset operations are lost or degraded?	This question refers to full facility operations. If the impact is minimal, this number will be low. If the facility is nearly shut down and all core operations cease, this number will be high.	Percentage 0–100	100%	
A3.1	How long does it take to transition between full facility operations and this degraded performance without backup?	This question refers to the length of time from full facility operations until the facility reaches the level of degradation defined in A3.	Time minutes/hours	0 minute	
Asset A Impact with Backup					
A4	Does the facility have a backup generator(s) that can be used in case of loss of external utility-provided electric power?	This question refers only to the backup capabilities stored onsite that would be immediately available in the event of a disruption.	Dropdown choice yes/no	Yes	
A4.1	How long does it take to transition operations to run on backup power?	This question refers to the length of time needed to start operating the backup.	Time minutes/hours	1–30 minutes	
A5	How long can the generator(s) run without offsite refueling (i.e., considers onsite fuel backup)?	This question refers to fuel stored onsite that would be immediately available.	Time hours/days	24–48 hours	
A6	Is there the potential to refuel the backup?	This question refers to the characteristics of the disruptive event that could prevent refueling (e.g., disruption of supply	Dropdown choice yes/no	Yes/no	

Number	Question	Additional Description	Response Format/Range	Typical Values	
		chain, disruption of transportation system).			
A6.1	How many times can the backup be refueled?	If the backup can be refueled indefinitely, enter 1000.	Number 1–1000	1–1000	
A7	Does the facility have uninterrupted power system (UPS)/battery backup?		Dropdown choice yes/no	Yes	
A7.1	How long does the UPS/battery backup run?		Time minutes/hours	30 minutes–2 hours	
A7.2	How is the UPS/battery backup connected to the system?	This question refers to the use of UPS/battery backup.	Dropdown choice <ul style="list-style-type: none">• In addition to backup generator(s)• To accommodate switch from external supply to backup generator(s)• Sole backup for loss of external supply	–	
A8	Once external utility-provided electric power service is lost, considering all backup, what percentage of asset operations are lost or degraded?	If the facility is fully operational or near fully operational, this number will be low. However, if electric power backups are only used for life safety or graceful shutdown, and most facility operations are not supported, the percentage of facility operations lost or degraded will be high.	Percentage 0–100	With generators 1–10% Without generators 100%	
Asset A Mandated Shutdown					
A9	Are there external regulations/policies that mandate the full facility shutdown after loss of electric power service, including backups?	This question refers to regulations that lead to the facility shutdown when there is not any electric power available even if some operations (mostly related to maintenance, safety and security) do not require electricity.	Drop-down choice yes/no	(Check EPA air permits for site operations and/or internal Health and Safety policies)	
A10	How long after loss of electric power, including backups, would mandatory full asset shutdown occur?	This question refers to the length of time required to activate the mandatory shutdown.	Time minutes/hours	(depends on answer to A9)	
A10.1	How long does it take to shut down full facility operations?	This question refers to the time required to safely shut down all facility operations.	Time minutes/hours/days	(depends on answer to A9)	

Number	Question	Additional Description	Response Format/Range	Typical Values
Asset A Resumption				
A11	Once external utility-provided electric power service is restored, how long does it take to resume back to full asset operations, if:	Note that some resumption activities may take place during the disruption, such as inspections, which may reduce the time to resume to full operations once electric power service is restored.	Not a response field	
A11.1	Facility is in full shutdown?	This question refers to resumption from full shutdown, which would be likely to include inspections as well as security and safety controls. This represents the maximum time required to restart (i.e., black start) the facility operation.	Time minutes/hours/days	2–5 days (cold start, assuming asset itself is not damaged)
A11.2	Facility is running on backup with core operations functioning?	Answer to this question is likely to be similar to the response to A4.1, the time required to transition to backup power.	Time minutes/hours/days	1–30 min
A11.3	Facility is running on backup, but without core operations functioning?	Answer to this question is likely to be higher than the response to A11.2; for example, if backup power sources only facilitate shutdown or operate basic life safety functions, but do not support core operations. Core operations will need to be restarted, which takes more time.	Time minutes/hours/days	2–5 days (cold start, assuming asset itself is not damaged)

Number	Question	Additional Description	Response Format/Range	Typical Values
ASSET B: Electric Power-Generating Plant				
Asset B Core Operations				
B1	What type of power-generating units are used at the facility?	This question guides what questions are needed for characterizing Asset B. For example, the section characterizing the impact with alternative fuel does not apply for natural-gas-fired generating plants.	Drop-down choice <ul style="list-style-type: none"> Natural-gas-fired generating plant Dual-fuel generating plant 	–
B2	What percentage of full <i>facility operations</i> are dedicated to performing <i>core operations</i> (e.g., production of key services/goods)?	This question is intended to distinguish between full facility operations and core operations, and to determine what percentage of operations performed at the asset are dedicated to the generation of electric power.	Percentage 0–100	90–99% (for all thermal generating plants)
Asset B Impact without Natural Gas Backup or Alternative Fuel				
B3	If external utility provided natural gas service is lost, without considering any backup (e.g., natural gas or alternative fuel), how soon would the full facility operations be impacted?	This question captures the time length between the disruption of Asset A until the facility is affected (i.e., how long the asset will continue to operate before being affected?).	Time minutes/hours	1–4 hours
B4	Once external utility-provided natural gas service is lost, without considering any backup (e.g., natural gas or alternative fuel), what percentage of asset operations are lost or degraded?	This question characterizes the percentage of operations at the facility that are supported through use of natural gas. Note that if natural gas is used solely to support core operations, the response to B4 should match the response to B2. However, if natural gas is also used for noncore functions, such as onsite heating, the response to B4 will be greater than the response to B2.	Percentage 0–100	90–100%
B4.1	How long does it take to transition between full facility operations and this degraded performance without backup (e.g., natural gas or alternative fuel)?	This question refers to the length of time from full facility operations until the facility reaches the level of degradation defined in B4.	Time minutes/hours	30 minutes-1 hour

Number	Question	Additional Description	Response Format/Range	Typical Values
Asset B Impact with Natural Gas Backup				
B5	Does the facility have a backup natural gas supply (e.g., onsite storage) that can be used in case of loss of external utility-provided natural gas?	This question refers to alternative natural gas supply, natural gas stored onsite, or line storage that can be accessed quickly in the event of a disruption to the main supply.	Drop-down choice yes/no	No
B5.1	How long does it take to transition operations to run on backup natural gas supply?	This question refers to the length of time needed to start operating the backup.	Time minutes/hours	–
B6	How long can operations run on backup natural gas without resupply?	This question characterizes how long the backup can operate without receiving additional supply from an outside source.	Time hours/days	–
B7	Is there the potential to resupply the backup natural gas?	This question refers to the characteristics of the supply chain and existing supply agreements.	Dropdown choice yes/no	–
B7.1	How many times can the backup natural gas be resupplied?	This question refers to the characteristics of the disruptive event that could prevent refueling (e.g., disruption of supply chain, disruption of transportation system). If the backup can be resupplied indefinitely, enter 1000.	Number 1–1000	–
B8	Once external utility-provided natural gas service is lost, considering all backup natural gas supplies, what percentage of asset operations are lost or degraded?	If the facility is fully operational or near fully operational, this number will be low. Similar to the response to question B4, this response should take into account core and noncore uses of natural gas onsite. For example, if the backup supports only core operations, but 5% of operations account for noncore uses of natural gas (e.g. onsite facility heating), then the response to B8 would be 5%.	Percentage 0–100	–

Number	Question	Additional Description	Response Format/Range	Typical Values
Asset B Impact with Alternative Fuel				
B9	Is there an alternative fuel source (e.g., petroleum, oil) available for facility core operations?	This question, and related questions, apply only if Asset B is a dual-fuel generating plant (question B1). If Asset B is a natural-gas-fired generating plant, the entire section does not need to be answered. All questions are grayed out.	Dropdown choice yes/no	Yes
B9.1	What alternative type of fuel is used?	The type of fuel affects the characteristics of the generating plant (e.g., time required to modify the furnace equipment [e.g., fuel injectors] or the existence of specific regulations).	Drop-down choice <ul style="list-style-type: none"> • Diesel/distillate Fuel • Residual fuel oil • Coal 	Diesel/distillate fuel
B9.2	How long does it take to transition operations to run on an alternative fuel source?	This question refers to the time required to transition to the alternative fuel supply and to modify the generating plant operations and equipment to be able to use/burn the alternative fuel.	Time minutes/hours/days	10 minutes-12 hours (depending on the number of generating units transitioned to alternative fuels)
B10	How long can operations run on an alternative fuel source without resupply?	This question specifically refers to Asset B capabilities and helps defining onsite storage of alternative fuel. It excludes external supply capabilities that are considered in question B11.	Time hours/days	1–2 days (depending on geographic location and size of facility)

Number	Question	Additional Description	Response Format/Range	Typical Values
B11	Is there the potential to resupply the alternative fuel source?	This question refers to the characteristics of the supply chain and existing supply agreements.	Dropdown choice yes/no	Yes
B11.1	How many times can the alternative fuel source be resupplied?	This question refers to the characteristics of the disruptive event that could prevent refueling (e.g., disruption of supply chain, disruption of transportation system). If the alternative fuel source can be resupplied indefinitely, enter 1000.	Number 1–1000	1–2
B12	Once external utility-provided natural gas service is lost, considering all alternative fuel supplies, what percentage of facility operations are lost or degraded?	If the facility is fully operational or near fully operational, this number will be low. This response should take into account core and noncore uses of natural gas onsite. For example, if the alternative fuel only supports facility operations, but 5% of operations account for noncore uses of natural gas (e.g., onsite facility heating), then the response to B12 would be 5%.	Percentage 0–100	0–10%
Asset B Mandated Shutdown				
B13	Are there external regulations/policies that mandate the full facility shutdown after loss of natural gas service, including natural gas backup and alternative fuel supplies?	This question refers to regulations that lead to the facility shutdown when there is no natural gas available even if some operations (mostly related to maintenance, safety, and security) do not require natural gas.	Dropdown choice yes/no	(Check EPA air permits for site operations and/or internal Health and Safety policies)
B13.1	How long after loss of natural gas, including natural gas backup and alternative fuel supplies, would mandatory full facility shutdown occur?	This question refers to the length of time required to activate the mandatory shutdown.	Time hours/days	(depends on answer to B13)
B14	Are there external regulations/policies that mandate the full facility shutdown if running on an alternative fuel source?	This question refers to regulations that lead to the facility shutdown when running on alternative fuel, for example, if there are environmental regulations that limit use of alternative fuels because of their emissions when burnt.	Dropdown choice yes/no	(Check EPA air permits for site operations and/or internal Health and Safety policies)

Number	Question	Additional Description	Response Format/Range	Typical Values
B14.1	How long after changing over to an alternative fuel source would mandatory full facility shutdown occur?	This question refers to the length of time required to activate the mandatory shutdown.	Time hours/days	(depends on answer to B14)
B15	How long does it take to shut down full facility operations?	This question refers to the time required to safely shut down all facility operations.	Time minutes/hours/days	(depends on answer to B14)
Asset B Resumption				
B16	Once external utility-provided natural gas service is restored, how long does it take to resume back to full facility operations, if:	Note that some resumption activities may take place during the disruption, such as inspections, which may reduce the time to resume to full operations once the natural gas main supply is restored.	Not a response field	
B16.1	Facility is in full shutdown?	This question refers to resumption from full shutdown, which would be likely to include inspections as well as security and safety controls. This represents the maximum time required to restart (i.e., black start) the facility operation.	Time minutes/hours/days	10 minutes–12 hours
B16.2	Facility is running on natural gas backup with core operations functioning?	Answer to this question is likely to be similar to the response to B5.1, the time required to transition to backup supply.	Time minutes/hours/days	N/A
B16.3	Facility is running on natural gas backup, but without core operations functioning?	Answer to this question is likely to be higher than the response to B16.2, for example, if backup power sources only facilitate shutdown or operate basic life safety functions, but do not support core operations. Core operations will need to be restarted, which takes more time for additional control.	Time minutes/hours/days	10 minutes–12 hours
B16.4	Facility is running on alternative fuel with core operations functioning?	Answer to this question is likely to be similar to that to B9.2, the time to transition to alternative fuel.	Time minutes/hours/days	10 minutes–12 hours (if running diesel/distillate fuel and depending on the number of generating units transitioned to alternative fuels)

Number	Question	Additional Description	Response Format/Range	Typical Values
B16.5	Facility is running on alternative fuel, but without core operations functioning?	Answer to this question is likely to be higher than the response to B16.4 if alternative fuel does not support core operations. Core operations will need to be restarted, which takes more time for additional control.	Time minutes/hours/days	N/A

Appendix B – Scenario 1

[Reset Scenario 1](#)

#	Define the Scenario
1	<p>If there is an interruption in the electric power supplied to Asset A, what is the anticipated duration of _____ hours</p> <p>electric supply interruption? _____ days</p> <p>_____ 2 weeks</p>
2	<p>Does Asset A provide natural gas required for Asset B <u>facility operations</u>? _____ Yes</p>
3	<p>Does Asset B provide electric power required for Asset A <u>facility operations</u> (e.g., production of key services/goods, business operations, life safety processes, maintenance activities, etc.)? _____ No</p>

Asset A: Natural Gas Processing Plant		
A1	What percentage of full <u>facility operations</u> are dedicated to performing <u>core operations</u> (e.g., production of key services/goods)?	95 %
Impact without Backup		
A2	If external utility provided electric power service is lost, without considering any backup, how soon would the full facility operations be impacted?	0 minutes hours
A3	Once external utility provided electric power service is lost, without considering any backup, what percentage of facility operations are lost or degraded?	95 %
A3.1	How long does it take to transition between full facility operations and this degraded performance without backup?	0 minutes hours
Impact with Backup		
A4	Does the facility have a backup generator(s) that can be used in case of loss of external utility provided electric power?	Yes
A4.1	How long does it take to transition operations to run on backup power?	15 minutes hours
A5	How long can the generator(s) run without off-site refueling (i.e., considers onsite fuel backup)?	24 hours days
A6	Is there the potential to refuel the backup?	Yes
A6.1	How many times can the backup be refueled?	2
A7	Does the facility have Uninterrupted Power System (UPS)/Battery backup?	Yes
A7.1	How long does the UPS/Battery backup run?	30 minutes hours
A7.2	How is the UPS/Battery backup connected to the system?	To accommodate switch from exter
A8	Once external utility provided electric power service is lost, considering all backup, what percentage of facility operations are lost or degraded?	5 %
Mandated Shutdown		
A9	Are there external regulations/policies that mandate the full facility shutdown after loss of electric power service, including backups?	Yes
A10	How long after loss of electric power, including backups, would mandatory full facility shutdown occur?	2 hours days
A10.1	How long does it take to shut down full facility operations?	minutes 1 hours days
Resumption		
A11	Once external utility provided electric power service is restored, how long does it take to resume back to full facility operations, if:	
A11.1	Facility is in full shutdown?	minutes hours 4 days
A11.2	Facility is running on backup with core operations functioning?	15 minutes hours days
A11.3	Facility is running on backup, but without core operations functioning?	minutes hours 2 days

Asset B: Natural Gas Fueled Power Plant		
B1	What type of power generating units are used at the facility?	Natural gas fired generating plant
B2	What percentage of full <u>facility operations</u> are dedicated to performing <u>core operations</u> (e.g., production of key services/goods)?	95 %
Impact without Natural Gas Backup or Alternative Fuel		
B3	If external utility provided natural gas service is lost, without considering any backup (e.g., natural gas or alternative fuel), how soon would the full facility operations be impacted?	minutes 1 hours
B4	Once external utility provided natural gas service is lost, without considering any backup (e.g., natural gas or alternative fuel), what percentage of facility operations are lost or degraded?	95 %
B4.1	How long does it take to transition between full facility operations and this degraded performance without backup (e.g., natural gas or alternative fuel)?	30 minutes hours
Impact with Natural Gas Backup		
B5	Does the facility have a backup natural gas supply (e.g., onsite storage) that can be used in case of loss of external utility provided natural gas?	No
B5.1	How long does it take to transition operations to run on backup natural gas supply?	minutes hours
B6	How long can operations run on backup natural gas without resupply?	hours days
B7	Is there the potential to resupply the backup natural gas ?	
B7.1	How many times can the backup natural gas be resupplied?	
B8	Once external utility provided natural gas service is lost, considering all backup natural gas supplies, what percentage of facility operations are lost or degraded?	%
Impact with Alternative Fuel		
B9	Is there an alternative fuel source (e.g., petroleum, oil, etc.) available for facility core operations?	
B9.1	What alternative type of fuel is used?	
B9.2	How long does it take to transition operations to run on an alternative fuel source?	minutes hours days
B10	How long can operations run on an alternative fuel source without resupply?	hours days
B11	Is there the potential to resupply the alternative fuel source?	
B11.1	How many times can the alternative fuel source be resupplied?	
B12	Once external utility provided natural gas service is lost, considering all alternative fuel supplies, what percentage of facility operations are lost or degraded?	%

Mandated Shutdown		
B13	Are there external regulations/policies that mandate the full facility shutdown after loss of natural gas service, including natural gas backup and alternative fuel supplies?	<input type="text" value="Yes"/>
B13.1	How long after loss of natural gas, including natural gas backup and alternative fuel supplies, would mandatory full facility shutdown occur?	<input type="text" value="8"/> hours <input type="text"/> days
B14	Are there external regulations/policies that mandate the full facility shutdown if running on an alternative fuel source?	<input type="text"/>
B14.1	How long after changing over to an alternative fuel source would mandatory full facility shutdown occur?	<input type="text"/> hours <input type="text"/> days
B15	How long does it take to shut down full facility operations?	<input type="text"/> minutes <input type="text" value="4"/> hours <input type="text"/> days
Resumption		
B16	Once external utility provided natural gas service is restored, how long does it take to resume back to full facility operations, if:	
B16.1	Facility is in full shutdown?	<input type="text"/> minutes <input type="text"/> hours <input type="text" value="4"/> days
B16.2	Facility is running on natural gas backup with core operations functioning?	<input type="text" value="15"/> minutes <input type="text"/> hours <input type="text"/> days
B16.3	Facility is running on natural gas backup, but without core operations functioning?	<input type="text"/> minutes <input type="text" value="8"/> hours <input type="text"/> days
B16.4	Facility is running on alternative fuel with core operations functioning?	<input type="text"/> minutes <input type="text"/> hours <input type="text"/> days
B16.5	Facility is running on alternative fuel, but without core operations functioning?	<input type="text"/> minutes <input type="text"/> hours <input type="text"/> days

Appendix C – Scenario 2

[Reset Scenario 2](#)

#	Define the Scenario
1	If there is an interruption in the electric power supplied to Asset A, what is the anticipated duration of _____ hours electric supply interruption? _____ days _____ 2 weeks
2	Does Asset A provide natural gas required for Asset B <u>facility operations</u> ? _____ Yes
3	Does Asset B provide electric power required for Asset A <u>facility operations</u> (e.g., production of key services/goods, business operations, life safety processes, maintenance activities, etc.)? _____ No

Asset A: Natural Gas Processing Plant		
A1	What percentage of full <u>facility operations</u> are dedicated to performing <u>core operations</u> (e.g., production of key services/goods)?	95 %
Impact without Backup		
A2	If external utility provided electric power service is lost, without considering any backup, how soon would the full facility operations be impacted?	0 minutes hours
A3	Once external utility provided electric power service is lost, without considering any backup, what percentage of facility operations are lost or degraded?	95 %
A3.1	How long does it take to transition between full facility operations and this degraded performance without backup?	0 minutes hours
Impact with Backup		
A4	Does the facility have a backup generator(s) that can be used in case of loss of external utility provided electric power?	Yes
A4.1	How long does it take to transition operations to run on backup power?	15 minutes hours
A5	How long can the generator(s) run without off-site refueling (i.e., considers onsite fuel backup)?	24 hours days
A6	Is there the potential to refuel the backup?	Yes
A6.1	How many times can the backup be refueled?	2
A7	Does the facility have Uninterrupted Power System (UPS)/Battery backup?	Yes
A7.1	How long does the UPS/Battery backup run?	30 minutes hours
A7.2	How is the UPS/Battery backup connected to the system?	To accommodate switch from exter
A8	Once external utility provided electric power service is lost, considering all backup, what percentage of facility operations are lost or degraded?	5 %
Mandated Shutdown		
A9	Are there external regulations/policies that mandate the full facility shutdown after loss of electric power service, including backups?	Yes
A10	How long after loss of electric power, including backups, would mandatory full facility shutdown occur?	2 hours days
A10.1	How long does it take to shut down full facility operations?	minutes 1 hours days
Resumption		
A11	Once external utility provided electric power service is restored, how long does it take to resume back to full facility operations, if:	
A11.1	Facility is in full shutdown?	minutes hours 4 days
A11.2	Facility is running on backup with core operations functioning?	minutes 15 hours days
A11.3	Facility is running on backup, but without core operations functioning?	minutes hours 2 days

Asset B: Dual Fuel Power Plant		
B1	What type of power generating units are used at the facility?	Dual fueled generating plant
B2	What percentage of full <u>facility operations</u> are dedicated to performing <u>core operations</u> (e.g., production of key services/goods)?	95 %
Impact without Natural Gas Backup or Alternative Fuel		
B3	If external utility provided natural gas service is lost, without considering any backup (e.g., natural gas or alternative fuel), how soon would the full facility operations be impacted?	minutes 1 hours
B4	Once external utility provided natural gas service is lost, without considering any backup (e.g., natural gas or alternative fuel), what percentage of facility operations are lost or degraded?	95 %
B4.1	How long does it take to transition between full facility operations and this degraded performance without backup (e.g., natural gas or alternative fuel)?	30 minutes hours
Impact with Natural Gas Backup		
B5	Does the facility have a backup natural gas supply (e.g., onsite storage) that can be used in case of loss of external utility provided natural gas?	No
B5.1	How long does it take to transition operations to run on backup natural gas supply?	minutes hours
B6	How long can operations run on backup natural gas without resupply?	hours days
B7	Is there the potential to resupply the backup natural gas ?	
B7.1	How many times can the backup natural gas be resupplied?	
B8	Once external utility provided natural gas service is lost, considering all backup natural gas supplies, what percentage of facility operations are lost or degraded?	%
Impact with Alternative Fuel		
B9	Is there an alternative fuel source (e.g., petroleum, oil, etc.) available for facility core operations?	Yes
B9.1	What alternative type of fuel is used?	oil
B9.2	How long does it take to transition operations to run on an alternative fuel source?	minutes 12 hours days
B10	How long can operations run on an alternative fuel source without resupply?	hours 7 days
B11	Is there the potential to resupply the alternative fuel source?	No
B11.1	How many times can the alternative fuel source be resupplied?	
B12	Once external utility provided natural gas service is lost, considering all alternative fuel supplies, what percentage of facility operations are lost or degraded?	5 %

Mandated Shutdown		
B13	Are there external regulations/policies that mandate the full facility shutdown after loss of natural gas service, including natural gas backup and alternative fuel supplies?	Yes
B13.1	How long after loss of natural gas, including natural gas backup and alternative fuel supplies, would mandatory full facility shutdown occur?	8 hours days
B14	Are there external regulations/policies that mandate the full facility shutdown if running on an alternative fuel source?	No
B14.1	How long after changing over to an alternative fuel source would mandatory full facility shutdown occur?	hours days
B15	How long does it take to shut down full facility operations?	minutes 4 hours days
Resumption		
B16	Once external utility provided natural gas service is restored, how long does it take to resume back to full facility operations, if:	
B16.1	Facility is in full shutdown?	minutes hours 4 days
B16.2	Facility is running on natural gas backup with core operations functioning?	minutes hours days
B16.3	Facility is running on natural gas backup, but without core operations functioning?	minutes hours days
B16.4	Facility is running on alternative fuel with core operations functioning?	minutes hours 1 days
B16.5	Facility is running on alternative fuel, but without core operations functioning?	minutes hours 3 days

Appendix D – Scenario 3

[Reset Scenario 3](#)

#	Define the Scenario
1	<p>If there is an interruption in the electric power supplied to Asset A, what is the anticipated duration of _____ hours</p> <p>electric supply interruption? _____ days</p> <p>_____ 2 weeks</p>
2	<p>Does Asset A provide natural gas required for Asset B <u>facility operations</u>? _____ Yes</p>
3	<p>Does Asset B provide electric power required for Asset A <u>facility operations</u> (e.g., production of key services/goods, business operations, life safety processes, maintenance activities, etc.)? _____ No</p>

Asset A: Natural Gas Processing Plant		
A1	What percentage of full <u>facility operations</u> are dedicated to performing <u>core operations</u> (e.g., production of key services/goods)?	95 %
Impact without Backup		
A2	If external utility provided electric power service is lost, without considering any backup, how soon would the full facility operations be impacted?	0 minutes hours
A3	Once external utility provided electric power service is lost, without considering any backup, what percentage of facility operations are lost or degraded?	95 %
A3.1	How long does it take to transition between full facility operations and this degraded performance without backup?	0 minutes hours
Impact with Backup		
A4	Does the facility have a backup generator(s) that can be used in case of loss of external utility provided electric power?	Yes
A4.1	How long does it take to transition operations to run on backup power?	15 minutes hours
A5	How long can the generator(s) run without off-site refueling (i.e., considers onsite fuel backup)?	24 hours days
A6	Is there the potential to refuel the backup?	Yes
A6.1	How many times can the backup be refueled?	2
A7	Does the facility have Uninterrupted Power System (UPS)/Battery backup?	Yes
A7.1	How long does the UPS/Battery backup run?	30 minutes hours
A7.2	How is the UPS/Battery backup connected to the system?	To accommodate switch from exter
A8	Once external utility provided electric power service is lost, considering all backup, what percentage of facility operations are lost or degraded?	5 %
Mandated Shutdown		
A9	Are there external regulations/policies that mandate the full facility shutdown after loss of electric power service, including backups?	Yes
A10	How long after loss of electric power, including backups, would mandatory full facility shutdown occur?	2 hours days
A10.1	How long does it take to shut down full facility operations?	minutes 1 hours days
Resumption		
A11	Once external utility provided electric power service is restored, how long does it take to resume back to full facility operations, if:	
A11.1	Facility is in full shutdown?	minutes hours 4 days
A11.2	Facility is running on backup with core operations functioning?	minutes 15 hours days
A11.3	Facility is running on backup, but without core operations functioning?	minutes hours 2 days

Asset B: Dual Fuel Power Plant		
B1	What type of power generating units are used at the facility?	Dual fueled generating plant
B2	What percentage of full <u>facility operations</u> are dedicated to performing <u>core operations</u> (e.g., production of key services/goods)?	75 %
Impact without Natural Gas Backup or Alternative Fuel		
B3	If external utility provided natural gas service is lost, without considering any backup (e.g., natural gas or alternative fuel), how soon would the full facility operations be impacted?	minutes 1 hours
B4	Once external utility provided natural gas service is lost, without considering any backup (e.g., natural gas or alternative fuel), what percentage of facility operations are lost or degraded?	95 %
B4.1	How long does it take to transition between full facility operations and this degraded performance without backup (e.g., natural gas or alternative fuel)?	30 minutes hours
Impact with Natural Gas Backup		
B5	Does the facility have a backup natural gas supply (e.g., onsite storage) that can be used in case of loss of external utility provided natural gas?	Yes
B5.1	How long does it take to transition operations to run on backup natural gas supply?	15 minutes hours
B6	How long can operations run on backup natural gas without resupply?	hours 2 days
B7	Is there the potential to resupply the backup natural gas ?	No
B7.1	How many times can the backup natural gas be resupplied?	
B8	Once external utility provided natural gas service is lost, considering all backup natural gas supplies, what percentage of facility operations are lost or degraded?	5 %
Impact with Alternative Fuel		
B9	Is there an alternative fuel source (e.g., petroleum, oil, etc.) available for facility core operations?	Yes
B9.1	What alternative type of fuel is used?	oil
B9.2	How long does it take to transition operations to run on an alternative fuel source?	minutes 12 hours days
B10	How long can operations run on an alternative fuel source without resupply?	hours 7 days
B11	Is there the potential to resupply the alternative fuel source?	No
B11.1	How many times can the alternative fuel source be resupplied?	
B12	Once external utility provided natural gas service is lost, considering all alternative fuel supplies, what percentage of facility operations are lost or degraded?	5 %

Mandated Shutdown		
B13	Are there external regulations/policies that mandate the full facility shutdown after loss of natural gas service, including natural gas backup and alternative fuel supplies?	<u>Yes</u>
B13.1	How long after loss of natural gas, including natural gas backup and alternative fuel supplies, would mandatory full facility shutdown occur?	<u>8</u> hours <u> </u> days
B14	Are there external regulations/policies that mandate the full facility shutdown if running on an alternative fuel source?	<u>No</u>
B14.1	How long after changing over to an alternative fuel source would mandatory full facility shutdown occur?	<u> </u> hours <u> </u> days
B15	How long does it take to shut down full facility operations?	<u> </u> minutes <u>4</u> hours <u> </u> days
Resumption		
B16	Once external utility provided natural gas service is restored, how long does it take to resume back to full facility operations, if:	
B16.1	Facility is in full shutdown?	<u> </u> minutes <u> </u> hours <u>4</u> days
B16.2	Facility is running on natural gas backup with core operations functioning?	<u>15</u> minutes <u> </u> hours <u> </u> days
B16.3	Facility is running on natural gas backup, but without core operations functioning?	<u> </u> minutes <u>8</u> hours <u> </u> days
B16.4	Facility is running on alternative fuel with core operations functioning?	<u> </u> minutes <u> </u> hours <u>1</u> days
B16.5	Facility is running on alternative fuel, but without core operations functioning?	<u> </u> minutes <u> </u> hours <u>3</u> days

Decision and Infrastructure Sciences Division

Argonne National Laboratory

9700 South Cass Avenue, Bldg. 221

Argonne, IL 60439-4854

www.anl.gov

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