Energy and Emergency Planning Integration Crosswalk (EEPIC)

Interdependency Planning

Interdependency Planning

MODULE OVERVIEW

Interdependency planning involves developing a state energy strategy that recognizes the relationships between critical infrastructure sectors. This module will specifically address interdependencies that directly impact grid operations and infrastructure to understand the risk of cascading impacts.

This module analyzes electric grid impacts through the lens of three FEMA Critical Lifelines (referred to as 'sectors' throughout the module): communications, energy, and transportation. These sectors were chosen due to their essential support to grid operations and their potential for cascading impacts if degraded or disrupted. They also require a specialized understanding of their capabilities to improve cross-sector coordination efforts.

Outline

HOW TO USE THIS MODULE

The module is split into three independent sections, each discussing sector-specific assets, their potential impact on grid operations, and how planning for the sector is impacted by the state's chosen Energy Security Strategy. The module, including the sections themselves, is written as a flexible reference and not intended to be prescriptive or used in sequence. Feel free to navigate this module in any order that suits your planning needs.

Step 1 — **Sector Overview**. Define the Critical Lifeline based on the Energy Security Strategies and understand how its loss impacts grid operations.

Step 2 — **Sector Asset Analysis**. Analyze 3-4 infrastructure asset types within the sector that are essential for grid operations.

Step 3 — **Grid Operations Impact**. Understand how outage duration within a sector impacts operations and examine how asset outages impact grid operability.

Step 4 — **Engagement Questions**. Provide examples and guidance on the questions to ask sector owners/operators to improve joint planning and coordination efforts.

Step 5 — **Strategy Implications**. Determine how each Energy Security Strategy shapes planning priorities and decision-making within the sector.

Interdependency Planning

OPPORTUNITY STATEMENT

Interdependency planning helps develop more robust and realistic emergency response plans by recognizing the crucial linkage between grid operations and the critical sectors it depends on, including communications, energy, and transportation. The grid provides the energy necessary to operate assets within these sectors that are critical to grid operations and their loss can have serious consequences for reliable operations. For example, the loss of fiber communication lines can disrupt remote visibility and control of grid assets by severing data links for Supervisory Control and Data Acquisition (SCADA) systems. State offices are well positioned guide stakeholders in surfacing these connections, where dependence on energy may not be obvious. Not every vulnerability can be fully resolved; the goal is to reduce the most consequential risks.This module examines operational dependencies and highlights opportunities to improve planning and coordination efforts.

GAPS

All Critical Lifeline Sectors Require the Grid, and Codependency varies	All critical lifeline sectors (i.e., safety and security; food, water, shelter; health and medical; energy; communications; transportation; and hazardous materials) depend on the grid to operate. However, many of these sectors do not directly enable grid operations. For example, a hospital needs electricity to run its machines but provides no benefits *to* the grid. This framework accounts for these sector-specific services and constraints to help users analyze dependencies that have direct impacts to the electric grid and response operations.
Visibility and Understanding of Sector-specific Assets	While evaluating which sectors are most essential to grid operations is challenging, there is the added problem of understanding the specific capabilities and relevant assets within those sectors. Stakeholders may be unaware of specific functions due to regulatory or technical reasons (e.g., data protection, or lack of specific software to view information). Additionally, the opaque nature of dependencies can make it difficult to pinpoint or recognize critical assets until a real-world failure occurs.

MODULE GOALS

Evaluate the interdependency planning concerns of critical lifeline sectors based on their importance to the grid.	Improve visibility and shared understanding of sector capabilities for state energy stakeholders.
Understand how power outages along critical lifeline sectors impact grid operations.	Support cross-sector emergency planning and coordination.

Sector Overview

SECTOR ORIENTATION

This module addresses the interdependencies between grid operations and the infrastructure that supports it. Specifically, it analyzes grid impacts through the lens of three FEMA Critical Lifelines—communications, energy, and transportation—identifying the assets within each that are most consequential to grid operations, rather than providing a comprehensive sector-wide analysis.

Each sector is covered in detail in the following pages. The descriptions below are intended to orient users to what this module covers for each sector. Use the individual sector sections for full asset definitions, analysis, planning considerations, and strategy alignment.

	Sector Definition
Communications	The communications sector underpins grid reliability by keeping operators connected to their systems and to each other. Its assets enable real-time monitoring, coordination, and data exchange that grid operators depend on during disruptions. This section specifically focuses on physical infrastructure (e.g., switching facilities), connectivity assets (e.g., cell towers), and dispatch and alerting assets (e.g., public safety answering points, or PSAPs).
Energy	The energy sector encompasses the interconnected network of power and fuel infrastructure that supports the function of all other sectors. Its assets are responsible for fuel availability and electric generation. This section specifically focuses on liquid fuels (diesel, oil, and propane) and natural gas. Energy programs and technologies that support electricity generation and management, such as demand response and virtual power plants, are growing in importance. However, they operate more as processes than fixed assets. Therefore, they do not fit within the asset-based analysis conducted in this module and are not discussed.
Transportation	The transportation sector connects the people, equipment, and materials needed for grid operations. Its assets span multiple jurisdictions and ownership structures, requiring early and constant coordination between stakeholders. This section specifically focuses on modal transportation: roadways (e.g., highways), rail systems (e.g., rail cars), and maritime assets (e.g., ports and barges).

Interdependency Planning

Communications Sector

Communications Sector Overview

SECTOR DEFINITION

The communication sector is foundational to grid reliability and resilience, enabling both system control and effective field operations. For the system, communications enables remote and real-time monitoring of grid assets and provides the data necessary for capacity monitoring and dispatching. On the field operations side, it enables coordination and connectivity with work crews, incident response stakeholders like law enforcement, and issuing public notifications to customers. Without reliable voice and data communications, whether lost to a power outage or a cybersecurity challenge, utilities lose system visibility and coordination efforts degrade, hindering restoration operations and exacerbating the impacts of grid disruptions to other sectors. Therefore, the main goal of assets in this sector is to maintain connectivity before, during, and after incidents.

STRATEGY ALIGNMENT OVERVIEW

Diversification	Economics	Resilience
Plan for increased dependency on small comms nodes that come with greater use of microgrids, DERs, Virtual Power Plants (VPPs), and inverter-based resources, incorporating comms nodes into microgrid planning and evaluating where co-location of assets may be required to maintain reliable operations.	Direct planning and investment effort towards BES-supporting communications infrastructure where data reliability underpins economically important areas, assets, and capabilities to protect or prioritize their operations during emergencies or restoration.	Work with emergency response stakeholders to identify and prioritize communications energy loads that support public safety, public health, and command-and-control during emergencies to support essential life-saving and life-sustaining functions.

GRID OPERATIONS OVERVIEW

Physical Infrastructure	Connectivity	Dispatch & Alerts
Physical communications assets, such as fiber optic relay sites, switching stations, and control centers, enable secure data exchange and facilitate remote management between field assets and system operators. These assets have the most impact for grid operations.	Assets that enable voice communication, such as Wi-Fi and cellular/telephone service, support real-time coordination between field crews and devices and external partners. If degraded, short-term backups are available, but effective alternative processes must be included in emergency plans.	Assets such as PSAPs and law enforcement stations enable incident reporting, information flow, and coordinated emergency response across jurisdictions. While they can provide key information for security, their loss has minimal impact to the grid's operation.

Asset Analysis

ASSET OVERVIEW

The connectivity and dispatch and alerting assets and capabilities provided by the communications sector allows stakeholders to maintain visibility and control of the grid. Theys are also important for effective response and coordination. When considering the grid more specifically, the importance of the services provided by these assets is also shaped by their load size and distribution across the system. The table below analyzes specific communications assets value to grid operations as a function of the services they provide and their energy loads.

Asset	Grid Service	Load Assessment	Evaluation
Backbone Facilities (Fiber Networks, Switching and Optical Relay Stations)	*Physical Infrastructure*: Connects comm. lines to transmit data between users and/or systems.	*Large, Centralized Loads*: Singular, central meeting point for multiple network lines, comms. providers, and data to be disseminated from.	These are high risk assets, serving multiple sectors and providers simultaneously and in a centralized location. Assets have battery or other backup, but risk increases as disruption duration extends past backup capability, having cascading impacts. More considerations are required for restoration (e.g., facility access, location).
Cellular Towers	*Connectivity*: Facilitates information exchange across distances and organizations.	*Small, Distributed Loads*: Location and availability mostly depends on network provider. Provides cellular coverage to a specific radius, so many are used to reach across a region.	These are a medium risk asset, used as primary capability to communicate with stakeholders or assets in different locations (e.g., field crews). They have backup generators, but risk can increase if fuel resources deplete and power is not restored. The number of assets requires significant logistics, complicating coordination and outage impacts.
PSAPs	*Dispatch & Alerts*: Facilitate incident reporting and info., coordination, and security across multiple jurisdictions.	*Medium, Distributed Loads*: Few are needed to serve large regions or communities. Acts as a main entry point for public safety and security information.	Low risk, indirect grid-providing asset that helps manage response efforts related to grid operations. By law, has 24 hours of backup capability. Having backup and fewer loads makes it easier to restore power for utilities and mitigates the need for contingency operations.

Grid Operations Impact

IMPACT OVERVIEW

A power outage affecting the communications sector can have profound impacts for grid operations. The impact is determined by three components: an asset's operational constraints (i.e., the ability for the asset to have power or operations restored quickly by the utility); the ability of the asset to operate in degraded conditions (e.g., backup platforms, systems, or processes); and the criticality of service provided by the asset to the grid. The table below outlines the impacts that the loss of each critical communications asset type has on grid operations at various outage durations.

Duration	Duration Analysis	Grid Impacts
≤6-12 Hours	Manageable duration that prompts switching to contingency procedures, backup communications platforms, or a form of manual operations. Noticeable impacts for grid operation and coordination efforts as backup power capabilities are strained or become inoperable.	***Cellular Towers*** Impacts depend on tower location, as each has varying criticality depending on the area they serve (e.g., critical facilities in area vs rural residences), services provided, and priority for restoration. Loss forces use of contingency comms platforms and procedures (e.g., radio, satellite phones) which can be strained over extended periods.
≥12-24 Hours	Certain contingency systems become degraded due to extended duration (e.g., backup power depleted). Connectivity losses complicate dispatching, field comms., and real-time information sharing. Slowed response activities due to reduced comms., working hours for crews, etc.	***PSAPs*** No direct grid impact, but response coordination can be degraded. Loss of power at 24+ hours can trigger gov't. involvement in response efforts. Impacts information flow and coordination for public safety and security needs allocated between stakeholders.
24+ Hours	Represents the highest risk for grid operations, with strained external coordination. Severely degrades dispatching, field comms., and real-time information sharing/monitoring. Increased risk of cascading failures, safety incidents, and response timelines.	***Backbone Facilities*** Backup power for these facilities begins to deplete after 24 hours, so coordination of additional fuel supply or restoring grid power is needed. Loss in general connectivity (i.e., voice, data, etc.) over large areas, due to aggregated service lines.

Engagement Questions

KEY IDEAS

Effective interdependency planning in the communications sector requires state stakeholders to actively engage energy and communications providers, emergency management agencies, and other partners (e.g., state and federal agencies) to understand how communications assets support grid operations and where gaps in understanding their capabilities and impacts of their loss exists.

The questions below are designed to prompt structured dialogue about emergency planning that improves visibility, clarifies roles, and aligns priorities across organizations. By addressing concerns such as operational limitations, stakeholders can improve their asset awareness and strengthen their ability to plan for incidents and implement resilience measures.

Existing Partners & Programs	Which comms providers and public agencies are essential to grid operations and emergency coordination, and how are they integrated into planning and response? What info-sharing agreements or mechanisms are needed?
Investment Gaps	Which assets or capabilities would improve system visibility and control during outages (e.g., backup power, redundant paths)? Where could joint investments between utilities and comms providers reduce shared vulnerabilities?
Policy & Regulatory Guidance	What barriers limit coordination, joint prioritization, or data sharing between utilities and comms providers? Where would state guidance improve alignment on comms and emergency response priorities?
Operational Capabilities & Limitations	How long can critical comms systems operate under degraded conditions before operations are significantly affected? How are cybersecurity vulnerabilities being planned for and mitigated? What impacts are likely?
Resource & Technical Needs	What resources are required to sustain comms capabilities during extended outages or degraded environments? What additional tools, data, or analyses are needed to better understand comms dependencies and operational limits?

Strategy Implications

STRATEGY - LIFELINE PLANNING CRITERIA

This section uses criteria-based evaluation to understand what implementing the Energy Security Strategies in planning would look like in practice with the communications sector. Rather than prescribe a single approach, it provides a structured framework for comparing how each strategy changes planning priorities, operational requirements, and the assets or capabilities needed to support grid operations. The table below highlights some key planning considerations and guiding questions that help evaluate how each strategy influences planning and decision-making within the communications sector.

Strategy	Considerations	Guiding Questions
Diversification	• Assess whether comms systems provide sufficient capability to monitor diverse energy portfolios (e.g., DER, IBR, conventional gen.). • Determine where additional comms nodes, redundant paths, or co-located systems are needed to maintain ops.	• What (additional) comms capabilities are needed to maintain system visibility and dispatch during both normal operations and disruptions? • How does our energy mix impact comms needs (e.g., geographic dispersion, dispatchability, etc.)?
Economics	• Work with comms and grid asset owner/operators to align comms capabilities and asset upgrades (e.g., new tech) with grid infrastructure projects. • Evaluate where improved data reliability and system visibility provide the greatest operational value.	• Where would improved comms visibility and control enhance support to large loads and critical facilities? • What is the appropriate, economical level of investment that will provide the most benefit to grid operation?
Resilience	• Identify comms assets/sites whose loss would significantly impair grid operations or emergency response capabilities. • Determine the best standards or methods for strengthening assets (e.g., infrastructure hardening, back-up power duration limits, etc.).	• What potential cyber or physical security risks could advanced technologies expose the system to? • How do we identify the most vulnerable and most critical comms assets/facilities? How can the risks to these be mitigated?
Resource Adequacy Nexus	• Evaluate whether backup or redundant comms systems and emergency comms plans (e.g., PACE plans) can support operations in degraded environments. • Identify and mitigate constraints that prevent comms asset improvement (e.g., provide financial incentive to comms providers to build infrastructure).	• What comms gaps could reduce system monitoring, delay response operations, or prevent other grid operations? • Do we have sufficient technical and procedural comms capabilities to support grid operations under normal and degraded conditions?

Interdependency Planning

Energy Sector

Energy
(Power & Fuel)

Energy Sector Overview

SECTOR DEFINITION

The energy sector consists of the entire inter/intrastate, connected network of electricity, oil, natural gas, and liquid fuels assets throughout the U.S. The main goal of assets in this sector is to facilitate the availability of fuel and its management for electricity generation. The sector has a crucial role in planning because it crosses state lines, enables the function of all other sectors, and depends on other sectors for its function, potentially amplifying the effects of energy sector supply disruptions. Also, the ability of the sector to reliably perform has a direct impact on the economic wellbeing and public safety outcomes of communities in the region.

Therefore, effective planning in this sector is necessary to avoid cascading challenges that erode regional resilience. This section analyzes the key assets and capabilities of liquid fuels (i.e., oil, propane, and diesel) and natural gas.

STRATEGY ALIGNMENT OVERVIEW

Diversification	Economics	Resilience
Flexibility of power sources is the main goal. There should be a strong mix of generation sources and fuel types (i.e., thermal and renewable) to prevent reliance on and cascading impacts stemming from disruptions in a specific fuel source.	Focus investment on infrastructure and resources that support cost-effective, large-scale energy generation and delivery. Planning decisions are heavily influenced by market signals, policy priorities, and regional economic conditions.	Mitigate vulnerabilities across generation, distribution, and transmission systems of all energy types by implementing advanced technologies or processes (e.g., alternate fuels for backup generation, asset hardening) to ensure grid survivability.

GRID OPERATIONS OVERVIEW

Liquid Fuels	Natural Gas
Liquid fuels (e.g., oil, propane, and diesel) and distillates are critical for routine energy operations and emergency support. They can be distributed across state lines and help provide backup generation when the BES is disrupted, supply fuel for (peaking) power plants and homes, and have direct uses in sectors such as transportation.	Natural gas is a critical resource in electricity generation, providing base load power and peaking capacity to support grid stability. It also has uses for heating and industrial processes. The sector relies on many specific components to function, including pipelines, gate stations, and terminals.

Asset Analysis

ASSET OVERVIEW

The assets necessary for grid operations in the energy sector focus on fuel availability and managed allocation of the fuel. It is important to note that disruptions can create a vulnerability feedback loop, where the loss of fuel limits generation and backup power capabilities, which has further impacts on grid operations. Additionally, the importance of the services provided by these assets is also shaped by their load size and distribution across the system. The table below analyzes the value of specific energy assets to grid operations, as a function of the services they provide and their energy loads.

Asset	Grid Service	Load Assessment	Evaluation
Liquid Fuels	*Production* The extraction or preparation of fuels	*Small, Distributed Loads* Sites serve specific functions to producing usable fuel and are located in various places.	Limited short-term impact unless multiple sites are simultaneously affected and for long periods. Provides fuel in a useable state to end users.
	Distribution & Storage (Refineries, Point of Delivery Stations) Movement and storage of fuel to end use/users	*Large, Centralized Loads* Aggregates fuel from multiple sources in a single location and serves many users (can receive, store, or distribute).	High operational load with many buildings. Provides BES-level generation fuel, backup capabilities, and other end use.
Natural Gas (NG)	*Management (Control Systems/Centers)* Facilitates all operations of the system, from production to end use	*Large, Centralized Loads* Single control center, managing large parts of network (e.g., flow, distribution).	Manages NG movement and (for gas utilities) monitors system. Loss can limit remote visibility, forcing manual ops for localized operators and utilities.
	Production, Transmission, Distribution, and Storage The NG system, from refinement to end use	*Small, Distributed Loads* Assets (e.g., city gate stations) spread across the system, controlling specific parts and movement of NG.	Each load type and subcomponents has varied operational criticality and use (e.g., control pressure vs move supply). Number of assets and location complicates response timelines.
	Transit Hub (Terminals) Areas for maintaining supplies of NG	*Large, Centralized Loads* Specific facilities with high operational load (can receive, store, and distribute NG).	Backbone for fuel availability No direct grid service; impacts appear after supply *from* hubs stops (after extended period.)

Grid Operations Impact

IMPACT OVERVIEW

The impact of disruptions to liquid fuel and natural gas assets is shaped by how long an outage persists, how central the affected asset is to managing the fuel's supply and system controls, and the asset's operational constraints. Generally, these assets can withstand short-term disruptions by using supply storage and operational capabilities (e.g., manual operations, flexible service contracts, mutual aid); however, their ability to support electricity generation degrades as outages extend and their own operations are impacted. The table below outlines the impacts that the loss of each critical energy asset type has on grid operations at various outage duration.

Duration	Duration Analysis	Grid Impacts
≤24 Hours	Manageable duration; ability to rely on storage supplies and contingency capabilities (e.g., manual operations). Coordination may be complicated if other dependencies are degraded (e.g., comms.), there are extenuating circumstances, or partnerships do not exist.	**Point of Delivery & Refinery Facilities** In short term, loss of a single site can be mitigated through storage use, alternate supply chain sources, or alternate fuel sources for power generation. Loss of asset operation limits the ability to replenish storage and move/produce fuel, and can constrain future fuel availability after disruptions end.
≥24-72+ Hours	Significant operational constraints (e.g., system pressure, field crew management). Requires increased coordination between operators, regulators, local/state/federal agencies, and dependent sectors to repair or mitigate impacts. Noticeable impacts for fuel end users may begin (e.g., flexible service contracts, storage depletion).	**City Gate Stations, Storage Facilities, & Gas Stations** Loss of an asset causes reduced fuel supply at the local/small region level for end-uses (e.g., homes, generators, backups), directly reinforcing the vulnerability feedback loop. Operators, emergency managers, and critical facilities may rely on stored fuel supplies that are depleting.
72+ Hours	Normal mitigation measures become ineffective or exhausted. Impacts cascade through the sector (fuel shortages reduce gen. capacity), and begin to have significant effects across the grid and other sectors, limiting total capabilities. Coordination enters multilateral or regional level to be effective.	**Terminals** Do not provide direct grid services. If supplies to and from terminals stop, after an extended amount of time, generation, storage, and backup capabilities degrade significantly. Loss of asset operations has impacts for the wider geographic area.

Engagement Questions

KEY IDEAS

Interdependency planning in the energy sector requires engagements across fuel producers and managers, utilities, state/federal regulators, and emergency management partners. The questions below are designed to help state energy stakeholders better understand how energy sector assets operate under stress, where coordination can be improved, and how planning, investment, and policy-related decisions can influence the impacts of disruptions across other dependent sectors.

By addressing concerns such as operational limitations, stakeholders can improve their asset awareness and strengthen their ability to plan for incidents and implement resilience measures.

Existing Partners & Programs	What existing planning forums, agreements, or coordination processes can be leveraged to improve visibility into energy sector challenges? What orgs. control sector functions most critical to grid ops?
Investment Gaps	Which assets or capabilities would reduce the risk of prolonged outages or cascading failures if targeted for investment? Where are current investment priorities not addressing fuel deliverability, backup generation, or resource flexibility needs?
Policy & Regulatory Guidance	What existing policies, regulations, or rules most influence fuel availability, restoration activities, and contingency operations? How could state-led action remove barriers to energy sector operations and cross-sector coordination?
Operational Capabilities & Limitations	How do operational constraints (e.g., fuel shortage, equipment failures, etc.) affect grid operations as outage duration extends? At what point do degraded operations at crucial assets begin to significantly impact system reliability and wider response?
Resource & Technical Needs	In what ways do state or energy sector stakeholders lack situational awareness during disruptions? What info is needed to define thresholds where degraded conditions of energy sector assets affect grid operations?

Strategy Implications

STRATEGY - LIFELINE PLANNING CRITERIA

This section uses criteria-based evaluation to understand what implementing the Energy Security Strategies in planning would look like in practice with the energy sector. Rather than prescribe a single approach, it provides a structured framework for comparing how each strategy changes planning priorities, operational requirements, and the assets or capabilities needed to support grid operations. The table below highlights some key planning considerations and guiding questions that help evaluate how each strategy influences planning and decision-making within the energy sector.

Strategy	Considerations	Guiding Questions
Diversification	• Consider where over-dependence on a fuel source currently exists and where alternatives would improve operational flexibility. • Evaluate how different resource/fuel combinations affect dispatch and back-up flexibility.	• What combinations of fuels and/or power generation technologies most effectively diversify the system? • How do existing economic or external barriers (e.g., cost-to-build, geographical limits, etc.) impact diversification planning?
Economics	• Consider whether economically attractive investments increase dependence on specific fuels, technologies, or nodes over time. • Evaluate which projects or (regulatory) standards enable capacity, economic, and/or load growth.	• What policies or investments are needed to promote least-cost/most-benefit large-scale infrastructure construction? • What risks to resilience or reliability are being accepted in pursuit of this strategy? Has our risk tolerance been reached?
Resilience	• Mitigate potential financial costs from resilience measures by incorporating diversification and economic strategy goals/considerations in planning. • Assess how back-up gen/systems, storage capabilities, or DERs can be used to sustain critical functions.	• What parameters around operating procedures and technologies should we set for resilience measures (e.g. islanding capabilities, tax incentives for DERs, etc.)?
Resource Adequacy Nexus	• Assess whether fuel availability (i.e., transmission/transportation and fuel supplies for gens and backup uses) is sufficient for normal and degraded operations. • Identify potential issues, such as capacity shortfalls, fuel limitations, and management or deliverability challenges.	• What cross-sector dependencies exist that could prevent the delivery and use of liquid fuels and natural gas? • What does 'resource adequacy' mean, capacity-wise, for our fuel or technology types?

Interdependency Planning

Transportation Sector

Transportation Sector Overview

SECTOR DEFINITION

The transportation sector is a network of several, independent modes of transit that move goods and passengers; the assets or nodes can be publicly or privately owned. The main goal of assets in this sector is to connect resources to distributed users by enabling the movement of fuel, equipment, personnel, and materials necessary to operate the grid. Effective planning in this sector is essential because transit systems underpin every aspect of grid and emergency response operations. Additionally, planning or response in this section is heavily influenced by the efforts of state or federal partners. This section analyzes the key assets within road, rail, and maritime transport.

STRATEGY ALIGNMENT OVERVIEW

Diversification	Economics	Resilience
Consider the different supply chains and concerns (e.g., obtaining, installing and repairing grid-related equipment) when planning for diversified resources, as alternative transit and supply capabilities may be needed to withstand disruptions.	Direct planning and investment priorities to transportation hubs and corridors that support the most critical energy assets or operations, in order to enable cost-effective and timely movement of fuel, equipment, and personnel.	Work with utility and transportation stakeholders to determine the access, delivery, and response coordination needed during emergencies, particularly around critical grid assets. Build or reinforce existing plans to ensure adequate transit planning.

GRID OPERATIONS OVERVIEW

Roadways	Rail Systems	Maritime
Roadways (e.g., roads, highways, interstates) are the primary way utilities access energy infrastructure. They enable movement of crews, equipment, and fuels needed for generation and response activities. These assets are managed at the state-level, and are crucial in facilitating response and access needs.	Rail systems are a major part of the energy supply chain, allowing for inter/intrastate movement of materials that cannot be transported by road, such as fuels and large equipment like transformers. Rail operations require coordination across jurisdictions, making pre-event planning essential.	Maritime assets (e.g., port access and barge traffic) are foundational to grid operations by supporting supply chain movement over waterways. They enable delivery of bulk fuels like coal and major grid components. These systems involve state, federal, and private stakeholders, requiring coordinated planning.

Asset Analysis

ASSET OVERVIEW

This section analyzes transportation assets based on their load characteristics and the impacts these assets have on grid operations and emergency management. It is important to mind the differences of this sector compared to communications and energy assets. First, transportation assets are owned by a wider set of state, federal, and private stakeholders, limiting utility's direct ability to impact response efforts and necessitating broader coordination efforts. Second, assets are more directly impacted by *prolonged* disruptions, as delays in fuel and material movement pile up. Lastly, the state has a major, primary role in enabling utilities' movement during disruptions (e.g., security, route clearance on highways, etc.). The table below analyzes specific transit assets value to grid operations, as a function of the services they provide and their loads.

Asset	Grid Service	Load Assessment	Impact Evaluation
Roads, Highways, & Interstates	*Roadways* Facilitate movement of small volume grid assets and fuels via truck	*Small, Distributed Loads* Road networks create redundant/flexible routes for utilities and emergency responders to reach assets.	Management and ownership of specific roads lies with state and local transit authorities. Critical for physical access to assets and movement of small fuel/component supplies; final layer for other transit assets (i.e., you still need to move by road sometimes). Roads have varying importance and priority for resources (e.g., interstates have more traffic).
Rail Cars	*Rail Systems* Facilitates movement of goods over long distances and across state lines via rail cars	*Medium, Centralized Loads* High capacity, cost-effective option for bulk fuels and heavy grid components across long distances to centralized railyards.	Rail cars and tracks cross jurisdictions, but railyards are concentrated and sometimes privately owned, requiring planning across stakeholders. "Last Mile" Problem for some end users that may still need to use roads/ports for delivery can create prioritization conflict. Fuel/equipment deliveries to grid operators using this method may be delayed, prolonging outages.
Port Access & Barge Traffic	*Maritime* Supports delivery of bulk fuels and heavy equipment over waterways using barges and ships	*Large, Centralized Loads* Supports movement of imported materials like coal and grid components to a few ports located on major navigable waterways.	Redundancy, routing goods through alternative ports, is possible but limited by whether those ports have the capacity to absorb the additional volumes. High operational load (i.e., receiving and distributing materials on various modes) for ports and barge traffic. Needed for strategic, long-term movement of supplies; has lowest risk to grid operations (in the short-term).

Grid Operations Impact

IMPACT OVERVIEW

The impact of transportation disruptions on grid operations is heavily influenced by the size and multi-jurisdictional, multi-stakeholder nature of its key assets, particularly in regards to planning and coordination priorities. Unlike assets directly managed or owned by single entities, transportation systems depend on disparate local and state agencies, private operators, and authorities with different priorities and capabilities. As disruptions persist, coordination across these organizations becomes more complex, impacting movement of fuel and grid components. The table below outlines the impacts that the loss of each critical transportation asset type has on grid operations at various outage duration.

Duration	Duration Analysis	Grid Impacts
≤6-12 Hours	Disruptions stem from traffic control or access restrictions (e.g., debris on roads). Disruptions are well managed by state-level stakeholders, like law enforcement or Department of Transportation (DOT), but working hours may become problematic over time. Has more immediate impacts for localized fuel or supply distribution.	**Roads, Highways, & Interstates** Restoration and response operations (e.g., fuel delivery, crew access for repairs) are degraded by poor road access. Local and state DOT stakeholders may need to prioritize which roads to manage (e.g., traffic, tree removal which is not done by utilities), affecting which assets are restored first.
≥12-24 Hours	Noticeable impacts for rail and maritime operations begin and compound (e.g., degraded or lost ability to load and move rail cars, barges, and ships); fuel deliveries slow or are paused. Response and coordination efforts become challenging as impacted, multi-jurisdiction stakeholders increase.	**Rail Cars** Sustaining generation or backup capabilities and repairing equipment becomes difficult as fuel and equipment deliveries are disrupted. Possibility of switching to alternative transit modes may be limited by the ability to move supplies by new mode (e.g., by road) or if other modes are disrupted.
24+ Hours	Significant backup of grid fuels and components occur as goods are unable to move from their entry or distribution point. Transportation challenges become a primary constraint of grid recovery and response operations.	**Port Access & Barge Traffic** Supply backlogs begin to cause regional fuel availability issues. Limited flexibility in sending goods elsewhere or using other transit modes. Coordination challenges escalate, with grid and transit operators, port authorities, state, and federal stakeholders all being involved.

Engagement Questions

KEY IDEAS

The transportation sector enables the movement of crews, fuels, and equipment essential to maintaining grid operations; disruptions can shift sector assets from a supporting function to a limiting factor. Effective interdependency planning in the sector requires state stakeholders to actively engage energy and transportation providers, emergency management agencies, and other partners (e.g., state and federal agencies) to understand how transportation assets support grid operations and where gaps in understanding their capabilities and impacts of their loss exists.

The questions below are designed to guide structured dialogue between stakeholders and help identify transportation-related planning risk and constraints.

Existing Partners & Programs

What agreements exist with stakeholders to support fuel deliveries, personnel movements, etc. during disruptions?

How are transportation stakeholders incorporated into state and utility emergency operations and plans?

Investment Gaps

Where do current capabilities create logistical bottlenecks for moving resources for critical grid operations?

Which improvements (e.g., port enhancements, alternate routes) would reduce delays in supporting grid operations?

Policy & Regulatory Guidance

Where do existing transportation rules create uncertainty about who can authorize movements and resource support?

How should the state define and communicate priorities for state resource support during multi-sector disruptions?

Operational Capabilities & Limitations

How will the state prioritize support (e.g., security, escorts, etc) to utilities and transportation stakeholders during disruptions?

What contingency procedures exist to manage transportation disruptions?

Resource & Technical Needs

How long can critical transportation assets and functions operate under degraded conditions, and what thresholds signal that constraints are beginning to affect grid operations and response efforts?

Strategy Implications

STRATEGY - LIFELINE PLANNING CRITERIA

This section uses criteria-based evaluation to understand what implementing the Energy Security Strategies in planning would look like in practice with the transportation sector. Rather than prescribe a single approach, it provides a structured framework for comparing how each strategy changes planning priorities, operational requirements, and the assets or capabilities needed to support grid operations. The table below highlights some key planning considerations and guiding questions to help evaluate how each strategy influences planning and decision-making within the transportation sector.

Strategy	Considerations	Guiding Questions
Diversification	• Develop or support contingency operations (e.g., alt routes, modal options, etc.) that maintain grid operations when primary methods are disrupted. • Assess potential impact of geographically dispersed infrastructure or multiple fuel types on transportation planning.	• Are contingency logistics capabilities plans sufficient to support response and grid operations under degraded (prolonged) conditions?
Economics	• Prioritize investments in transportation assets and capabilities that increase fuel throughput and reduce delivery constraints for gen assets and major customers. • Evaluate whether transportation planning is aligned with demand growth, generation needs, and fuel supply shifts.	• What important or critical routes or assets are being overlooked for investment because they do not offer the greatest economic return? • How can investments be better allocated to improve transportation nodes while avoiding creating single points of failure?
Resilience	• Integrate utility and transportation stakeholder response plans to establish shared access procedures and resource allocation protocols. • Develop decision criteria for allocating state resource to transportation assets that sustain grid operations.	• What measures—procedural or technological—would best support grid operations during disruptions? • How can we balance differences in ownership and authority over assets among stakeholders and account for them in the planning process?
Resource Adequacy Nexus	• Work with transportation and utility stakeholders to build shared understanding of needs in emergency plans, like resource needs and timeline constraints. • Establish guidelines for providing state resources and assistance to utilities during disruptions (e.g., clearing hwys).	• Where does logistics capacity (i.e., timeliness of deliveries) become the limiting factor in maintaining or restoring grid operations? • How will the state prioritize and coordinate transportation assistance to utilities?