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Electric Infrastructure Security Council

SECTOR BLACK SKY PLAYBOOK

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ABSTRACT

The Electric Sector Black Sky Playbook contains the current framework for managing the risk associated with long duration, multi-region power outages associated with Black Sky Hazards. This document is designed to comprehensively address Black Sky resilience issues through all phases including Preparation/Mitigation, Response, Restoration and Recovery)

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V 2.0

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Role of the EPRO Sector Black Sky Playbook

This Playbook is designed to provide an evolving framework for recommended guidelines to manage risks of long duration, multi-region power outages associated with emerging "Black Sky" hazards.

This Playbook will be consistently updated and reviewed using the EPRO Sector Steering Committee process through consultation with sector professionals and mangers. This playbook contains the latest consolidated school of thought on the unique challenges posed by wide area, long duration outages. It provides guidelines to help individual entities strengthen their own resilience measures, develop focused operational plans and assess external support needed to address these severe hazard scenarios.

Sector Background

The Electric Sector is responsible for the design, construction, and operation of the electric grid, which is one of the world's largest, most complex machines. In the US alone, there are approximately 7,700 power plants and 300,000 miles of transmission and distribution lines. The components of the grid are supported by a very large infrastructure that supplies and delivers fuel, chemicals, and water by rail, barge, truck, and pipeline. Tens of thousands of highly skilled workers plan, operate, and maintain the grid. Complex computer systems provide monitoring and control of electrical and mechanical systems.

Ownership of the grid is fragmented. There are numerous utilities that may be privately owned, owned by their customers, or owned by local, state, and federal governments. Regulation of the grid is a combination of state public service commissions and the Federal Energy Regulatory Commission (FERC). The owners and users of the Bulk Electric System (BES) are subject to mandatory and enforceable reliability standards promulgated by the North American Electric Reliability Corporation (NERC) and approved by FERC.

The transmission system is monitored by Reliability Coordinators, who have a wide area view that may cover multiple transmission owners. Generation may be controlled by individual utilities, or by a regional market place. Delivery of power and energy to the ultimate retail customer is by Distribution providers who deliver power to the ultimate retail customer. These providers may purchase power on the wholesale market, or they may be part of a vertically integrated utility.

The North American electric grid is very robust. The grid is designed to survive the loss of multiple components without cascading, wide area outages. Most major area outages are the result of severe weather, such as a hurricane or an ice storm, damaging the low voltage distribution system in a relatively localized area. These weather events, even if very severe, rarely result in power outages that last more than a few days. Most of the load lost during the 2003 Northeast Blackout, which impacted generating stations and higher voltage transmission facilities, was restored within 24 hours.

Resilience planning for "grey sky" events is a particular strength for the Electric Sector. The FERC and NERC recently audited the Electric Sector's black start ability to recover from a grey sky event, and gave industry good marks. However, as a general statement, Black Sky events are considered to have a high impact, but occur only in low frequencies, and there has been little investment in resilience measures

for this higher level of threat. This attitude is slowly changing, and some utilities are incorporating EMP protection in new control centers and for substation control houses.

Sector Black Sky Environment

There are a multitude of serious issues facing the Electric Sector if it is impacted by a Black Sky event. Many are related to supplying adequate amounts of fuel to black start generators, emergency generators, nuclear power plants, natural gas fired generators, and dual fueled generators. Communications may be severely impacted by a Black Sky event, and situational awareness and the ability to control is critical to restarting the grid.

- Increased dependence on natural gas generation
    - Not fuel secure
    - Electric driven gas pipeline compressors
    - Pipeline operation depends on SCADA and communications
    - Pipeline tariffs (FERC regulated) not aligned with Black Sky conditions
- Lack of emergency generation
    - Water/Wastewater systems lacking in emergency generation
    - Limited availability of emergency generation through FEMA/USACE
    - Limited availability of emergency generation through commercial sources
- Fuel Storage for emergency generation
    - Most emergency generation has inadequate onsite fuel supply for Black Sky recovery
- Dual Fuel Generator Fuel Supply
    - Most dual fuel generators have inadequate fuel supplies for Black Sky recovery
- Electric Utility Planning
    - Most utilities do not have plans for Black Sky, Black Start recovery
    - No identification of secure enclaves for Black Sky, Black Start
    - No identification of critical loads for Black Sky events (these loads may be different from prioritization of loads for a grey sky event)
    - Little electric utility engagement in issue except for Transmission areas
- Nuclear Power
    - Little engagement in Black Sky issues
    - Emergency generator onsite fuel supply is designed for grey sky events
    - Limited ability to load follow with nuclear generation
- Regulation
    - Most utilities have not engaged regulators on Black Sky preparedness
    - Regulators have not yet explored the issue of cost recovery for just and reasonable expenditures for Black Sky preparedness
    - Environmental regulations may inhibit operation of dual fuel and emergency generation for extended testing.
- Cyber Security

- Concern have been expressed that NERC regulations are not best practices

- Communications
  - Normal communications may be severely interrupted after a Black Sky event. Equipment may be damaged, back up diesel generation for cell and other communications sites may be inadequate.
- Skilled Personnel
  - A Black Sky event will likely damage grid equipment. Internal resources may be inadequate to test and repair equipment following a Black Sky event.

Sector Model Overview

The EPRO Electric Subsector is made up of organizations that own, operate, and use the electric grid. The three major components of the grid include Generation, higher voltage Transmission, and lower voltage Distribution. There are approximately 7700 individual power plants in the US, with multiple generation units at most plant sites. There are 300,000 miles of transmission and distribution lines serving the US market. The electric utility business model varies considerably from state-to-state. In the Southeastern US, most utilities are vertically integrated. They own the generation, transmission, and the distribution facilities to serve their native retail and wholesale loads. Much of the regulation for this business model comes from the state public service commission. In other parts of the country the three components are disaggregated. There is a market operator (for generation) and a Transmission Operator (RTO) for transmission. These two entities may cover multiple states. The distribution provider is the final link to the load. In the market structure model, transmission and generation are FERC regulated, and distribution is the responsibility of the state public service commission.

The BES in the US and Canada is divided into three electrically independent parts: the Eastern Interconnection, the Western Interconnection, and ERCOT (Texas). These interconnections have very little, if any, electrical connectivity and operate independently. Except at FERC (regulation) and NERC (standards), there is little integration between the regions. As a general statement, FERC does not regulate entities in ERCOT because it is contained in one state (Texas).

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Sector Model Graphic

Version 1.0 high level graphical model **of** your sector. Lower level models can be developed to help document the complexity of the sector. ***To be provided.***

Sector Black Sky Strategic Mission Statement

In the wide area of impact, long duration power outages, and disrupted environments associated with Black Sky hazards, the most critical goals for societal health and continuity will be systematic, timely and well-prioritized power grid restoration, while simultaneously enabling the largest possible numbers of people to "shelter in place" during the multi-week or longer restoration period.

While many tasks must go forward to enable these two goals, among the most critical will be properly focused resilience investment and planning by the Electric Subsector, along with the corresponding investment and plans by partner sectors, required to support the Electric Subsector's measures.

Electric Subsector Black Sky Mission: Develop and implement focused resilience investment and operational plans required to allow for timely, well-prioritized power restoration following a Black Sky event, along with definition and coordination of requisite support from partner sectors.

Strategic Mission Priorities Matrix

Under normal circumstances the reliability of service to retail utility customers in North America is extremely high. Statistically, outages caused by failures of the bulk grid itself (generation, transmission) are minimal. Most outages are caused by localized damage to the distribution system from trees, vehicles, and equipment failure, and affect only those customers near the failure. Following a Black Sky event, there will be a different picture of service reliability. A Black Sky event will has the potential to shut down the entire grid in a multistate region, and there will be no electrical service except from emergency generators located at a customer's site. Depending on the amount of damage to black start generators and key transmission and substation facilities, it may be several days or more before initial service is restored to preplanned, critical load.

There is a strategy applicable to restoration to the grid following a Black Sky event. Over a period of days secure enclaves of generation, transmission, and load will be established. However, without the support of the interconnected grid, the reliability of these enclaves may be poor due to the unstable nature of

the small amount of the grid that is online. The secure enclaves will be expanded as fuel secure units and possibly nuclear generation is brought online, along with an equal amount of load. There will be a preplanned prioritization of loads to be served, and rotating blackouts may be an important part of the transmission operator's tool box. When the secure enclaves are interconnected to nearby enclaves, and then ultimately to the entire grid, near normal operations can resume. At that time, the grid will be relatively stable and as much load as is available to be served will be connected to the grid. Reliability for the load served at this stage of recovery should be similar to pre-event reliability.

Phase	Priority	Mission
I Establish secure enclaves	High	Service to critical loads, including water/wastewater, natural gas delivery infrastructure, nuclear power plant switchyards, fuel secure generation units. Reliability may be poor due to the difficulty of matching generation to load, an incomplete transmission grid, and the potential of generation trips.
II Expand and interconnect secure enclaves	High	Expand service to include denser municipal enclaves, critical supply chain loads, and lifeline services. Reliability may be less than pre-event reliability.
III Interconnect enclaves to the grid	High	Establish "near normal" operations, and serve as much load as is capable of being served with near normal reliability.

Black Sky Decisions Overview

The first priority of the Electric Sector after a Black Sky event will be implementing the Black Sky black start plans. To implement the plans, decisions will be required about which generation to start, which transmission cranking paths to energize, where personnel should be dispatched to inspect and repair equipment, and what communications systems can be relied on to provide situational awareness and control.

The Transmission Operator's Black Sky black start plans should have black start generation and cranking path transmission facilities identified, as well as initial critical loads. However, after a Black Sky event, some equipment expected to survive to implement the plan will be damaged or otherwise non-available, while some non-hardened equipment may be available. The Transmission Operator must decide how to implement the plan, and whether to modify the black start plan based on an assessment of the availability of generation and transmission.

To the extent natural gas transportation infrastructure may be available to serve generation, gas fired generation may be included in the Black Sky black start process.

The Black Sky event may have damaged communications. The Transmission Operator must determine what communications system(s) are available, whether SCADA is reliable, and how to communicate with equipment and personnel in the field or at generation stations.

The Transmission Operator should identify key locations that require communication with the control center about equipment status, and then dispatch personnel to those locations. The Transmission Operator should also identify key equipment that must be inspected before operation, and repaired, if necessary.

The initial Electric Sector decisions will be: what communications systems to utilize, what generation to start, what transmission to energize, and what critical loads should be served.

Black Sky Decisions Matrix

Phase	Priority	Decision
I	High	Is the Black Sky black start plan still viable? What alterations in the plan are required based on actual equipment status?
I	High	How will fuel availability impact generation availability?
I	High	What communication(s) systems are available and should be used? Is SCADA reliable?
I	High	Where to send technicians to inspect and repair equipment?

Sector Black Sky Situational Awareness Overview

Situational awareness is key to the successful operation of the electric grid. Transmission Operators cannot guess about the status of generation, transmission facilities, and load without endangering personnel, potentially damaging equipment, and risking unstable operation. Situational awareness means that the Transmission Operator knows the status of any piece of equipment connected to the grid, and knows the grid frequency. The Transmission Operator must know if a generating unit is synchronized to the grid and its approximate electrical output. Transmission system circuit breaker status and approximate system load levels are required for reliability and for matching generation levels with load levels. Under normal circumstances, system control and data acquisition (SCADA) equipment provides the situational awareness picture in the Transmission Operator's control room. Automatic generation control (AGC) from the control center often regulates the generation. After a Black Sky event, communications channels for SCADA may be disrupted, and key information may only be

provided verbally to the control center from field personnel. Some Transmission Operators drill this procedure to ensure they can retain adequate control of their portion of the grid.

Natural gas fired generation is a significant portion of the generation in the US. Gas fired generators are less complex than coal fired units and lend themselves to faster inspection, repair, and operation than a coal fired unit. However, unlike a coal plant, there is no onsite storage of fuel available. Knowledge of the availability of natural gas transportation infrastructure allows the Transmission Operator to understand the availability of generation within its footprint.

Communications between generation stations and field personnel are necessary for control and operation of the grid. If SCADA is available and reliable, these functions can be performed by the Energy Management System in the control room. If SCADA is not available, verbal communications manual data presentations can substitute.

The ability to expand and interconnect secure enclaves is dependent on the availability of generation, transmission, and load serving equipment. Communications on the status of equipment allow the Transmission Operation to plan expansion of the enclaves.

The Transmission Operator has the ability to build the secure enclave, and interconnect enclaves within the Operator's area. However, the Transmission Operator may not have the visibility of other parts of the grid to allow interconnection with neighboring utilities or systems. The Transmission Operator must have communication with the region's Reliability Coordinator to safely and efficiently build the grid. As a minimum, verbal communications must be established between the Operator and the Coordinator to permit interconnections of enclaves with the grid without threatening system reliability.

Priority Information Requirements Matrix

Information	Source	Priority	Confidence Level
Initial status of electric grid transmission, generation, distribution	SCADA, verbal communications from the field	High	High – must have confidence in information in order to initiate black start restoration plans
Status of critical natural gas delivery infrastructure	Verbal communications with natural gas transportation sources	High	High - Must have confidence in fuel delivery capability in order to restart and operate critical gas fired generation
Instructions on operation of generation and substation equipment	SCADA, EMS, verbal communications with field personnel and generation stations	High	High – Breaker status and operation, load information, and generation levels critical to black start
Time to repair and return to service non-functional equipment	Verbal communications with field and generation personnel	High	High – Information required to implement secure enclave growth and expansion

Status of regional grid and instructions from Reliability Coordinator	Verbal or electronic with Reliability Coordinator	High	High – Information required to interconnect secure enclaves with neighboring systems

Sector Initial Actions

The initial actions of the Electric Sector after a Black Sky event will be focused on implementing Black Sky black start plans. These plans are similar to the NERC required black start plans, except that the generation and transmission cranking paths will be composed of facilities that have been hardened, and can be expected to be functional. The initial objective will be to energize secure enclaves of generation, transmission, and critical loads. Critical loads include water and wastewater treatment facilities, natural gas delivery infrastructure, and nuclear power plant switchyards. The second step will be to incorporate additional fuel secure generation, transmission, and loads into the enclaves. Finally, the enclaves will be interconnected with each other and with neighboring utilities until load serving capability is at a "near normal" level.

Sector Initial Actions Matrix (V2/V2.5/V3)

Priority	Initial Action	Desired/Required Outcome
1	Situational Awareness – After a Black Sky event, the grid will most likely be deenergized. Before any component of the electric grid can be reenergized, the Transmission Operator must know the status of equipment related to the section of the grid that is part of the black start plan. Are breakers open or closed? Are black start generators available or out of commission? Are critical loads able to accept electric service?	Determine what parts of the grid are intact, and what is out of service. Determine the extent that Black Sky black start equipment is damaged. Establish black start sequence.
	Communications – After a Black Sky event, communications may be completely interrupted. Communications are critical to providing situational awareness to the Transmission Operator. Communications are also vital for initiating the black start sequence. SCADA must be tested for operability and functionality. Voice communication via cell phone and radio and emergency systems must be tested.	As a minimum, verbal communications established with generation stations and field personnel. Additionally, electronic communications via SCADA established to black start and nuclear generation, and substations that are parts of the cranking paths, greatly enhance the

		Transmission Operator's ability to black start.
	Energize black start generation, cranking path transmission, and pick up critical loads within secure enclaves.	Initial generation is placed on line, a backbone transmission system is energized, and service begins to initial, critical loads.
	Expand secure enclaves to include nuclear generation, fuel secure generation units, and additional loads (municipal enclaves)	Nuclear generation safety systems are powered from the grid rather than from consumption of diesel fuel in onsite emergency generation. Nuclear generation is now in the position of considering a restart. Secure fuel units are on line to minimize the risk of fuel related loss of generation. Loads are added to the grid in amounts equal to the new generation.
	Interconnect secure enclaves with each other, and with assistance from the Reliability Coordinator, establish interconnections with neighboring grids. Stabilize the grid, and increase loads.	The grid is stable, with acceptable voltages and line flows. N-1 reliability may be established. Loads over a wide area are served.
	Establish "near normal" operations, and serve as much load as is capable of being served. Test, evaluate, and repair equipment and communications, control, and protection systems.	All load capable of being served is energized. As equipment and systems are restored to operation, the grid returns to normal utility operations and reliability.

Internal Sector Requirements

Black Sky planning will typically include hardware investments and expanded operational planning to enable these systems to operate in degraded equipment, communications, and fuel delivery modes.

Secure Enclave Resilience Measures

Black Start and Tier1/Other important Generators

Black start, and fuel-secure, Tier 1 generation should have a high priority for hardening against Black Sky threats. These generation units should be protected to allow for a safe shutdown – without damage – in the event of a Black Sky event, and a rapid restart (or if not running at the time of the event, an assured, rapid start.) Hardening should extend to onsite emergency generation, critical control equipment, station batteries, emergency lubricating oil pumps, and other equipment critical to the startup of the generation.

Cranking Path Transmission

Cranking path transmission should have at least one level of relay protection that is either hardened against a Black Sky event or is impervious to its effects, such as electromechanical relays. The substation facilities associated with the cranking path transmission should also receive sufficient hardening to permit the energization and operation of power transmission.

Control Centers

Control centers should be hardened to the extent needed to provide the vital situational awareness the system operators require for the restart and control of the electric grid. This would include hardening of communications systems, computer systems, and power supply to the facility. Some U.S. utilities are taking the approach of fully integrated hardening of the entire facility. Control centers should develop methods of maintaining situational awareness through voice communications and manual updating of screens, or even paper charts, if there is loss of SCADA communications.

Critical Facilities

Power utilities should harden Secure Enclave facilities used to serve previously identified facilities critical to the operation of the electric generation and to the grid. Critical facilities may also include lifeline services such as water and waste water facilities.

Fuel Supply Infrastructure

Power utilities should make resilience investments to harden their facilities that service the fuel supply infrastructure. The movement away from coal-fired generation with its substantial on site fuel storage places more reliance on other types of generation with little local onsite storage. Power supply to gas pipeline compressor stations and to other critical gas infrastructure will facilitate the supply of natural gas to electric generation facilities. Power supply to diesel fuel storage and distribution assets will ensure that diesel fuel flow can be maintained in the supply chain for continued delivery to emergency generators, dual fuel generators, and other critical fuel consumers. Even though the majority of gas pipeline pumping stations are currently self-powered, there is a move toward powering compressors with electricity. Even self-powered pumping stations are controlled with electronic equipment that may be vulnerable to EMP effects.

Nuclear Power Plants

Nuclear power plants consume diesel fuel for emergency generators to operate safety systems in the plant when there is a loss of offsite power to the plant switchyard. This use of diesel fuel comes at a time when normal resupply is likely to become disrupted, and there will be increased

demand for diesel fuel from other priority users. Utilities should make resilience investments in the increased onsite storage of diesel fuel at the nuclear plant site, above and beyond that required by current regulation, wherever possible. Secondly, power utilities should make investments in the protection of transmission facilities connecting fuel secure "sister units" to the nuclear power plant in order to provide offsite power, and in some cases, allow nuclear generation to participate in the Black Sky restart process.[1] Grey Sky system restoration may take several days, or one to two weeks, at most. Typically nuclear plants are restarted at the end of the restoration sequence, when the grid has stabilized. A Black Sky restoration event with a much longer restoration time period may reorder priorities to consider the restart of nuclear plants earlier in the restoration sequence. Restoration of off-site power to the nuclear power plant switchyard is critical to facilitating nuclear plant startup early in the restoration process, rather than waiting until the end of the system restoration process.

Secure Fuel Supplies

Dual Fuel Storage Increases

Supplies of the secondary fuel for dual fuel generating stations should be enhanced to ideally provide approximately 30 days of run time on the secondary fuel. Because of the nature of a Black Sky event, it is likely that the supply of the primary fuel will be disrupted for an extended period of time and the ability to resupply the secondary fuel may be also disrupted. Therefore, extended secondary fuel stocks, even if not at a 30 day level, are necessary to allow operation of the unit until normal fuel delivery is available for the generation fleet. Storage of larger quantities of liquid fuels will also require monitoring and treatment to avoid contamination.

Co-locate Black Start Plants with Fuel Infrastructure

As noted above, a Black Sky event is likely to interrupt the normal resupply of fuel to generation stations. Fuel supply for black start plants should become a siting consideration, just as the availability of transmission service is a consideration. When practical, future black start gas fired generators should be strategically sited near major pre-existing fuel storage facilities, natural gas storage, and oil and liquefied natural gas (LNG) terminals.

Increased Natural Gas Storage Adjacent to Black Start Plant

As a hedge against Black Sky outage effects on gas gathering and long distance gas transmission, measures could be taken to further increase gas storage capacity of underground facilities that are located near major power plants and other critical users.

Increased LNG Storage

Where underground construction is not geologically practical, construction of LNG facilities – if/where they can be cost effective – should be considered as an alternative means to support fuel resilience for power generation.

Emergency Generator Fuel Storage

[1] EPRO Black Sky Protection Initiative: http://eiscouncil.org/Protection/ItemDetails/60

Many critical facilities have onsite emergency generators, however fuel storage for these generators is typically sized for short duration emergencies. This onsite storage should be increased to at least seven days of normal use, to allow time for system-wide emergency generator refueling during a Black Sky event.

Chemicals

Generation facilities require consumables other than fuel to operate reliably. For example, chemicals are required for the control of boiler water quality, and hydrogen is required to cool generators. Consideration should be given to increasing the onsite supply of essential chemicals.

Operational Black Sky Resilience Measures

Black Sky Restoration Plans – expand existing plans to include Black Sky, EMP, and other causes of extended outages.

Every region in the United States maintains black start plans, procedures, capabilities, equipment testing and exercises that must comply with the North American Electric Reliability Corporation (NERC) Reliability Standard EOP-005-2, "System Restoration from Blackstart Resources," and other regulatory mandates. Planning should be extended and modules should be added to these black start plans so that the plans address Black Sky hazards, such as severe space weather, earthquakes, coordinated physical assault, and especially EMP.

Trained Workforce

Black Sky hazards are expected to cause significant hardware damage distributed over very large regions, and restoration will typically require far more engineering support staff than under ordinary conditions. EMP damage to electronic equipment will probably be undetectable without skilled testing, placing greater demands on support staff.

Given the number of power companies that would be affected, sharing corporate staff between companies will likely be insufficient to address this shortfall.

Maintaining a large, skilled workforce is costly and difficult. Power utilities should make investments in the training and cross training within their organization of technical personnel in the skills necessary to address the damage that could occur during a Black Sky event. Enhanced training may be required to ensure technicians have the skill sets necessary to maintain both electronic and electro mechanical relay systems, if electro mechanical relays are retained as part of transmission system hardening. Basic emergency training could enable skilled personnel to utilize less skilled assistance to enhance their effectiveness. Emergency operations plans using minimum system protection requirements rather than fully redundant systems could lessen the demand for skilled technicians and engineers. The Certified Power Recovery Engineering Teams Initiative addresses this scenario by utilizing engineering personnel normally working with companies or government agencies outside the power industry as an emergency resource.[2]

Strategically Located, Generous Spares

[2] Certified Power Recovery Engineering Team Project: http://eiscouncil.org/Protection/ItemDetails/63

Black Sky events are likely to cause extensive damage to utility facilities. An EMP event, for example has the potential to cause the failure of electronic devices, such as system protection relays and control devices. These devices are not readily available on short notice in large quantities. A resilience measure to mitigate against damage is having a generous quantity of spares available in strategic locations.

Investments in spare components that are essential to Black Sky recovery should be made by the power industry. Spare components sensitive to EMP exposure such as transmission protective devices (relays), electronic test equipment, generator control and protection components, communications components, and hand held devices should be protected, where appropriate, in EMP secure enclosures and should be staged near the expected need.[3]

Emergency Communications and Training

A Black Sky event will have an adverse impact on communications systems. The electric power industry should invest in sufficiently hardened communications that will allow communications between control centers and generation stations, field personnel, reliability coordinators, and state and federal officials handling the emergency. Utility personnel should be trained in the use of these communication systems, and utilities should conduct regular drills and exercises.[4]

Planning for use of an appropriate emergency communication system for internal and external communication and data, and use of a synergistic emergency situational awareness and decision support tools, will be essential to accommodate both internal operational plans and coordination with external sectors. As an example, utilities may review and utilize, as a basis for these plans, the planned Emergency Communication (BSX) System architecture, recently developed for this purpose.[5] This architecture will have clear lines of authority on how the capabilities will be used and shared among the many entities that will depend upon them.

Expanded Maintenance and Testing

Emergency generation and dual fuel units will be critical to Black Sky black start success. Regular maintenance and testing of these types of generation equipment should become normal practice to continuously ensure successful execution of the role that generation will play in black start procedures.

Emergency generators should be periodically operated at full load to ensure that equipment will be able to perform their functions.

Dual fuel units should be started and operated – at full load – on their secondary fuel on a periodic basis to ensure that equipment operates correctly and plant operators remain familiar with secondary fuel operating techniques.

[3] See comments by David K. Owens, Executive Vice President, Business Operations, EEI at Electric Infrastructure Security Summit V http://eiscouncil.org/Summit/Archive/35

[4] *Ibid*

[5] EIS Council, Emergency Communications (ECOM) Project: http://eiscouncil.org/Protection/ItemDetails/62

EMP hardened spaces should be inspected and tested periodically to ensure that the shielding effectiveness has not been degraded.

Strong procedures should be in place to avoid unauthorized modifications to EMP hardening that could reduce effectiveness. For example, unauthorized penetrations of shielded enclosures should be avoided.

Internal Sector Requirements Matrix

Phase	Priority	Requirement
		Black Start/Tier 1 Generation Units
		Cranking Path Transmission
		Control Centers
		Critical Facilities
		Fuel Supply Infrastructure
		Communications
		Nuclear Power Plants
		Dual Fuel Storage
		Emergency Generator Fuel Storage
		Critical Chemicals
		Black Sky Black Start Plan Modules
		Trained Workforce
		Generous Spares
		Emergency Communications (BSX)
		Resilience Related Testing and Maintenance

External and Cross Sector Dependencies Overview

The Electric Subsector will be able to meet its mission requirement only if it has assured support from other sectors, to supply those services and resources that lie outside its normal capabilities. Defining the sector's required external support – and coordination with the appropriate sectors – is a crucial part of development of the Black Sky Protocol.

Protected Enclave Hardening

The Secure Enclave is the basic building block for recovery from a Black Sky event. The Secure Enclave is a subset of the electric grid capable of operating without external power from the grid, and because it accomplishes the goal of recovery of the electric grid while avoiding the necessity of hardening the entire grid, is a cost effective method of providing grid resilience.

Power utilities should work with regulators to encourage the hardening of the generation, transmission, and distribution facilities within the Secure Enclaves, and to adopt design standards that incorporate facility hardening techniques in new facilities. Regulators should provide the power industry with cost recovery for these resilience measures.

Dual Fuel Generation

Increased Secondary Fuel Storage

Even the widest possible distribution of fuel-switching capabilities will be of little resilience value when gas flows are interrupted unless generating stations have the secondary fuel they need to operate. On-site storage of secondary fuel offers the greatest value for resilience in Black Sky events.

The power industry should work with zoning boards, environmental regulators and other officials and stakeholders in power resilience to include resilience considerations in assessing specific fuel storage construction proposals. When practical, future gas generators might be strategically sited near major pre-existing fuel storage facilities and terminals. In addition, regulatory measures to assure maintenance of adequate storage levels of secondary fuels for critical dual fuel generators should be made a priority.

Emergency Waivers – Regulatory, Environmental, and Supply Chain Considerations

The power industry should work with State Public Utility Commissions and federal agencies (including the Environmental Protection Agency, FERC/NERC, DOE and others) to consider emergency waiver authorities and triggers for secondary fuel use, to allow more effective resilience planning and investment. Relief by FERC from market and reliability regulations may be appropriate. At the federal level, existing authorities to be examined and potentially utilized in this assessment should include those provided for in the Stafford Act.[6] At the state level, relief from regulations related to trucking of diesel fuel should be examined.

Cost Recovery for Dual Fuel Storage/Operations

Market rules and regulations should allow for the cost recovery for dual fuel generators.

In part due to the cost of seeking emission permits and installing necessary pollution control equipment, new dual-fuel generators and their fuel systems are more expensive to procure than their gas-only counterparts, and are more expensive to operate and maintain. The power industry should partner with regulators and other stakeholders in power resilience to examine how financial inducements might be created to encourage the construction of dual-fuel generators. Market rules and other regulations should

[6] See comments by David K. Owens, Executive Vice President, Business Operations, EEI at Electric Infrastructure Security Summit V http://eiscouncil.org/Summit/Archive/35

explicitly provide for the cost recovery of dual fuel storage construction and inventory carrying costs.

Incentivize Fuel Switching Capability

Power utilities should work with regulators and with generation markets to create special incentives to provide fuel-switching capabilities for generators that support black start operations.

In January 2016, the "FERC-NERC-Regional Entity Joint Review of Restoration and Recovery Plans" recommended that studies be made of possible strategies for replacing lost coal-fired black start resources, and of factors to be included in replacing them (including geographical diversity and fuel switching capabilities). As those studies go forward, they should develop targeted incentives and cost recovery mechanisms for dual fuel generators serving as black start resources. [7]

Gas Supply During Black Start Restoration

Emergency Waivers - Avoid Curtailment of Service to Generators

Regulatory "Curtailment Policies" provide for curtailing gas deliveries to industrial customers, including power grid generators, to prioritize delivery to residential customers when a power outage or other factors reduce pipeline gas flows. During a severe, long duration power outage, this prevents power grid generating stations from producing electricity, resulting in less electricity to those very same residential customers, and also possible shutdowns of electric gas pipeline compressors that would further reduce gas flows, causing a "vicious cycle" that quickly becomes a serious societal problem.

Power utilities should coordinate with regulatory authorities to authorize emergency waivers to avert curtailments to power generators during Black Sky events. Many state governors already have the authority to declare an energy emergency when they determine that the health, safety, or welfare of their citizens is imminently threatened by gas supply shortages. These emergency authorities should be revised to provide that when an especially severe event occurs, including those that would fall into the category of Black Sky events, governors can temporarily revise state curtailment policies and state environmental rules in order to make preservation of gas service to power generators a top priority.

Firm Gas Delivery Contract Cost Recovery

Market rules and regulatory mechanisms should allow for the recovery of the additional costs of firm versus interruptible gas delivery contracts.

[7] Federal Energy Regulatory Commission (FERC) and the North American Electric Reliability Corporation (NERC), "FERC-NERC-Regional Entity Joint Review of Restoration and Recovery Plans," January 29, 2016, http://www.ferc.gov/legal/staff-reports/2016/01-29-16-FERC-NERC-Report.pdf

Many state utility regulators who approve regulated utility cost recovery are sensitive to the additional cost that accompanies firm pipeline transportation. However, such firm contracts can greatly reduce the likelihood of gas curtailments in Black Sky hazards. Generation companies should work with regulators to develop options to provide for the additional funding firm contracts require.

Information sharing with Pipeline Industry

Restoration and recovery operations in a Black Sky hazard scenario will be complex, and information sharing will be vital to allow lifeline infrastructure utilities to pool their resources, address critical issues and optimize restoration. Regulators and lawmakers should address the challenges associated with anti-trust laws that have a negative effect on such information sharing between companies, especially in the fuel industry.

As one effective approach, regulators can create temporary solutions that can be enacted during large-scale outages and disasters

Support for Emergency Generator Fuel Delivery

Normal supply chain arrangements may fail during Black Sky recovery and the ability to obtain diesel fuel for emergency generators may be curtailed. This would be especially critical for nuclear power plants and for other key facilities.

The power industry should become engaged in the formation of the National Emergency Power Commission (NEPC). One objective of the NEPC Initiative is to support Black Sky restoration planning through emergency diesel fuel distribution.[8]

Support for Chemical Deliveries

Normal supply chain arrangements for important chemicals required for electric generation operation during a Black Sky recovery may fail, limiting the ability of generation to operate.

The power industry should become engaged in the formation of the National Emergency Utility Consumables Commission (NEUCC), which has an objective of developing the capability nationwide of supplying critical chemicals to the water and energy sectors.[9]

Water Supply for Generation Station Use

A number of generating stations utilize purified waste water or public water supplies for cooling tower makeup, or other plant uses. The power industry should identify those water / waste water systems that are critical to generation station operation and ensure that those loads: 1) are included as part of the critical loads to be served by the electric utility's protected enclaves; and, 2) the water / waste water systems understand and support the role they play in maintaining the availability of critical electrical generation.

NGO Requirements

[8] The National Emergency Power Commission Initiative: http://eiscouncil.org/Protection/ItemDetails/64
[9] The National Emergency Utility Consumables Commission Initiative: http://eiscouncil.org/Protection/ItemDetails/65

Critical Personnel and Family Support: Utilities will need to supplement their own critical personnel and family support activities, to assure their labor force will be available. Mass care NGOs can play a crucial role in this area, and will require such information from electric utilities to enable them to plan and train to provide such support.[10]

External and Cross Sector Requirements Matrix

Requirement Area	Priority	Requirement
Financial - Regulatory		Regulatory agencies should approve the cost recovery of Black Sky resilience measures, such as system hardening, increased onsite storage of dual fuels, increased levels of spare parts
Financial – Regulatory and Markets		Regulatory agencies and generation market places should provide financial relief for operation and maintenance of dual fuel units that are identified as Black Sky black start units
Operations – Natural Gas Delivery Priority		Regulatory and tariff requirements that limit the supply of natural gas units to generation should be examined and modified as applied to Black Sky events.
Financial – Fuel and Regulatory		Market mechanisms should be developed to allow the recovery of firm gas transportation costs for generation units identified as Black Sky black start units.
Communications (Physical)		Communications providers should examine the resilience of their systems that support the Electric Sector. The Electric Sector typically relies on multiple sources for communications. This would include the internet, cell phones, public telephone, and in some cases, satellite. The Electric Sector also has internally provided communications such as fiber, radio, and microwave.
Chemicals – Supply Chain		Generators rely on certain chemicals, in addition to food, for operation. Those entities that are part of this supply chain should have secure communications with the utility, and plans for delivery of critical supplies after a Black Sky event.
Water - Operations		Some generating stations rely of treated wastewater for cooling. These wastewater systems should provide resilient facilities to serve critical generation.
NGO		Mass care NGOs can play a role in providing support to utility critical workers and their families.

[10] See comments by David K. Owens, Executive Vice President, Business Operations, EEI at Electric Infrastructure Security Summit V http://eiscouncil.org/Summit/Archive/35

Sector Specialized Resource Requirements Overview

The Electric Sector requires a number of key resources to successfully restore service after a Black Sky event. The resources revolve around fuel: for black start generating units, dual fuel generating units, emergency generation, and natural gas delivery. Resources also revolve around spare equipment. Much of the equipment supporting the electric grid is potentially sensitive to EMP. System protection devices, generation control systems, communication systems, maintenance equipment and SCADA all contain electronic components that are often connected to metallic conductors that could convey voltage surges from an EMP event. Generous spare parts stored in a protected environment are a resiliency requirement. Chemicals are also a key resource. Like water systems, generating stations have a number of chemicals that are critical to operation. Pollution control devices often cannot be bypassed, and require chemicals to remain in operation. Power plant steam boilers require chemicals to maintain water purity in order to avoid tube failure. Generators require hydrogen for cooling. Human resources are also key to the Electric Sector. The internal staffing for the normal maintenance of system protection, control, and communications equipment will be inadequate to support the necessary testing and repair of EMP sensitive electronic equipment in a Black Sky environment. A source of trained technical personnel will be essential to expedite recovery.

Sector Commodity Specific List Matrix

Phase	Commodity	Estimated Quantity	Potential Source
	Diesel Fuel	TBD	
	Spare parts and equipment	TBD	
	Chemicals for generation stations	TBD	
	High tech manpower to supplement existing personnel, capable of testing and repairing communications, control, and protection equipment	TBD	

Sector Black Sky Communications Overview

The ability to communicate after a Black Sky event is critical to the Electric Sector. Without a two way exchange of data, and the ability to direct the operation of system equipment, the Transmission Operator will be greatly hampered in its ability to control and operate the grid. Voice communications can supplement SCADA data exchange, if there has been planning and training to simulate loss of communications. Data is required to provide the control center with situational awareness, and the ability to talk with field personnel in order to control equipment is essential in the event of the loss of SCADA.

Sector Communications Matrix

Phase	Communications Requirement	Coordinated Cross Sector Element
	Voice communications between generating stations, substations, control centers, critical loads, and field personnel	Internal to Sector
	SCADA communications between control center and generating stations and critical substations	Internal to Sector
	Voice and electronic communications between control center and Reliability Coordinator	Internal to Sector
	Voice communications with critical supply chain elements for fuel, consumables, etc.	External to Sector
	Voice or electronic communications with natural gas transportation providers	External to Sector (ONG)

Sector Black Sky Assessment Tool (s) Overview (V2/V2.5/V3)

List and discuss the various areas where assessments would add value. Use a simple approach. For each assessment listed there will be an associated Assessment Tool in Annex A.

- Sector Overall Resilience Assessment – Annex A -1

Note: Draft A-1 December 2016; Version 2.0 Required for Winter 2017/ Version 3.0/2018 ESC – Fully Complete by May 2019.

Sector Black Sky Planning Requirements

There are numerous best practices that can be adopted by the Electric Sector to provide resilience for the existing system, incorporate resilience measures into new construction, and to plan and train for Black Sky events.

NERC standards require Transmission Operators and operators of black start generators to have, test, and drill black start plans and procedures. These Transmission Operators should incorporate a Black Sky module into their black start plans. These Black Sky modules should recognize the more severe conditions that will exist in the aftermath of a Black Sky event than occur during a normal “grey sky” event or a cascading outage caused by equipment failure. Black start drills should incorporate total loss of communications or other Black Sky features such as damaged equipment.

Installation of Black Sky resilience measures in new construction is easier, and less costly than retrofitting existing facilities. Utilities and generators should consider modifying design practices to

incorporate resilience measure in new construction. These measures could include the use of fiber cable rather than metallic cable for control and communications. Incorporation of six wall shielding in new control houses and control centers, limiting points of entry into protected space, utilization of metallic doors with RF shielding, and waveguide protection ventilation are other examples of design enhancements for new construction.

Sector Best Practices Matrix (On-going)

Area of Operations	Recommendation	Expected Improvement
Planning	Enhance current black start procedures to include a BSky element	Many current black start plans do not assume damaged equipment, loss of fuel infrastructure, and complete loss of communications
Planning	Perform regular drills for Black Sky, black start events	Black Sky events are more severe that normal black starts. Equipment may be damaged and communications may be degraded
Design	Incorporate resilience measures into design practices and specifications for new facilities and equipment	More cost effective to include resilience in new construction than retrofitting
Planning	Identify generation, transmission, and substation facilities that are critical to Black Sky black start	Provide direction on where to apply resilience measures
Fuel	Dual fuel units that are part of the Black Sky Black Start plans should have significant on site storage of the secondary fuel	Provide for the extended operation of dual fuel units to ensure the ability to start up secure fuel units.
Fuel	Work with the natural gas transmission provider to understand the gas transportation network facilities that are critical to delivery of gas to generating units. Ensure those facilities are resilient to a black sky event.	Ensure the ability to deliver natural gas to critical generating units after a Black Sky event

Integrated and/or Shared Planning Actions (V3/3.5/V4)

To be provided in later versions

Planning Actions Matrix

Response Area	Shared Planning Requirement/Interface Point	Cross-Sector(s) ID

Sector Black Sky Resilience Considerations Overview

There are a number actions and investments the Electric Sector should take to improve electric grid resilience against a Black Sky Event.

The normal staffing levels of technicians and engineers at an electric utility is designed to maintain a system under normal conditions. During a grey sky event, such as an ice storm or a hurricane, assistance is usually provided by technicians on loan by utilities outside of the storm area. A Black Sky event will be widespread enough that outside assistance may not be available. In the event of a coordinated cyber-attack, outside utilities may be reluctant to provide assistance because of the possibility they will soon be attacked. The EPRO Certified Power Recovery Engineering Team Project is a method of increasing the availability of trained technicians that could work under the supervision of existing staff.

A Black Sky event such as EMP may damage communications systems. The EPRO BSX communications project is developing the architecture for a communications system that would withstand an EMP burst, and satisfy the Electric Sectors need for emergency communications that would provide situational awareness and command and control after a Black Sky event.

Resilience Initiatives Matrix

Initiative Title	Initiative Description/Cost	Expect Outcome
Certified Power Recovery Engineering Team Project	Developing a certified, supplemental high-tech manpower surge capability for lifeline utilities and their partners by drawing from aerospace, high-tech companies.	Adequate skilled manpower to test and repair damaged communications, protection, and control equipment
Emergency Communications BSX	Develop a resilient communication system that will provide voice, and possibly some data, transmission in the event of failure of telephone, SCADA, internet, and cell phone communications	Provide the minimally acceptable ability to maintain post Black Sky event situational awareness and control

Sector Black Sky Regulatory Impacts and Issues Overview

There are several areas of regulatory oversight of the Electric Sector that hinder resilience investment, impede training and preparation for a Black Sky event, or have the potential to slow down Black Sky recovery efforts.

The EPRO concept of secure enclaves provides for only the most critical facilities receiving resilience investments. By limiting the facilities to be hardened, the cost of resilience is reduced compared to the cost of hardening an entire electric grid. However, resilience still has a cost associated with it, and a regulatory method must be developed to assist the utility industry and regulatory bodies in determining a just and reasonable, cost effective level of investment. The utility must be assured that the cost of retrofitting existing critical facilities will be recovered, or it cannot make the investment. The incremental cost of incorporating resilience measures in new construction likewise must be recovered. Utilities and state and federal regulators should come to an agreement on what is just and reasonable.

Dual fuel units require a considerable amount of onsite storage in order to be prepared for a Black Sky event. There are fixed costs associated with this inventory, as well as maintenance costs required to maintain fuel quality. Dual fuel units should be periodically operated on the secondary fuel to ensure that they will successfully operate in an emergency. Because the secondary fuel is generally more expensive than the primary fuel, the fuel cost differential is a cost that will require recovery. If the dual fuel generation is part of a marketplace, the generators and the market operator should work to develop market mechanisms to incentivize the dual fuel capability.

Environmental regulations may limit the period of time that a liquid fueled generating unit can operate because of air quality. This may limit the amount of time that emergency generators can be operated for testing purposes. Both dual fuel units and emergency generators should be operated routinely to ensure they are capable of performing their functions. The utility industry and state and federal regulators should work collectively to ensure environmental regulations do not inhibit the maintenance of Black Sky capability for select generators.

During the restoration of the grid following a Black Sky event, it seems intuitive that the need for electrical power and lifeline facilities would override any regulation of any type. Anecdotally, this viewpoint is not universally held. There are numerous regulations that address power system operations (NERC Standards), air quality (EPA), natural gas service priorities, trucking, and other issues that could affect Black Sky restoration. Industry, government, and regulators should review regulations and explicitly remove impediments to a Black Sky recovery.

Sector Regulatory Matrix

Area of	Issue	Recommended Solution/Resolution

Operations		
Finance	Black Sky resilience measures have costs associated with design standards, construction, maintenance, and increased levels of spare parts. Electric utilities require assurance that reasonable expenditures may be recovered.	State public service commissions and Federal regulators should develop a methodology for evaluating the reasonableness of Black Sky resilience investments and provide for cost recovery in rates, or through other mechanisms.
Fuel	Black Sky black start dual fuel units require a substantial amount of onsite storage of the secondary fuel. There are financial barriers for onsite storage of secondary fuels related to the cost and maintenance of the fuel.	Generation markets should develop features that would financially incentivize dual fuel generators to maintain onsite storage for Black Sky recovery. These markets should also provide compensation to the generators when they operate in dual fuel mode for testing to prevent financial harm from out of market dispatch.
Fuel, Operations	Environmental regulations limit the time duration for burning liquid fuels for dual fuel units. Removal of regulatory barriers for routine testing of dual fuel units on secondary fuels would provide assurance that the units will be capable of operating after a Black Sky event. Diesel fueled emergency generators may also have time limits based on air quality rules that may limit the amount of routine operation for testing and maintenance.	Air quality regulations should be amended so that generating units designated as Black Sky related dual fuel units are provided sufficient regulatory relief to allow periodic operations for testing purposes. Emergency diesel generators for critical facilities should be provided sufficient regulatory relief to allow periodic operations for testing purposes.
Fuel	Much of the US generation is fired by natural gas. Current tariffs and regulations may provide a higher priority of service after a disturbance to other types of gas transportation customers than units that would participate in a Black Sky black restart.	Market rules and natural gas transportation tariffs should be amended to provide priority delivery service after a Black Sky event to generating units designated as critical to Black Sky recovery.
Fuel	Many gas fired combustion turbine generating units rely of non-firm gas delivery service because of the cost of firm gas transportation, and the lack of assurance that the generator will recover these costs.	Market rules and regulatory policies should be modified to provide for the cost recovery of firm gas delivery service for generating units identified in Black Sky black start restoration plans.
Supply Chain	Trucking regulations that impact the size of a load or the length of time drivers may work could impede delivery of critical resources after a Black Sky event. Large equipment such as transformers may need	State and federal regulatory agencies should put in place automatic exemptions to selected regulations that inhibit recovery from a Black Sky event.

	immediate movement. Critical diesel fuel will likely be transported to the Black Sky area from a distance.	

Sector Black Sky Essential Critical Infrastructure (MC) Overview (V3/3.5/V4)

Describe the most essential elements of the sectors infrastructure to achieve resilience. This section should address only those items that unique or mission essential to the sector. You will likely have a handful of items for each element of the sector model.

Sector Critical Infrastructure Matrix (V3/3.5/V4)

Element	Function

Sector Black Sky Specialized Skill Training Requirements Overview (V3/3.5/V4/V5)

Describe the mission critical sector identified skills/positions that must be filled to accomplish resilience. Start with Assessment and move through, Response, Restoration and Recovery. This should not be a laundry list of all positions. These are the agreed upon most critical positions and the associated training or certification requirement.

Sector Specialized Skill Training Requirements Matrix (V3/3.5/V4/V5)

Phase	Position/Skill	Training/Certification Requirement

Annex A – Assessments (On-going)

Sector Overall Resilience Assessment (V2)

Annex B – Regulatory Issues Detail Statements (On-Going)

Issue Statement 1

- Statement
- Decision Authority
- Required Documentation – To justify/document decision
- Resiliency Investment statement
- Plan Requirements
- Training Requirements
- Liability Statement/3rd Party Protection Issue
- Explicit requested legislative changes/Insurance/Assurance/3rd Party Indemnification

Annex C – Communications Requirements (V2/2.5/3/4)

Communications Requirement 1

- Internal/Planned Format/Path
- External/Planned Format/Path
- Explicit Model
    - Who
    - What
    - When
    - Strategies (back up)
    - Bandwidth requirement (actual and notional)
    - Format
    - Priority