Fuel Requirements for Black Start Resources Hiatus Activity Review Part 1

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FRBSR Roadmap

Stage 1 FRBSR Work

2019 – 2020

- Level of Fuel Assurance
- Universal Fuel Assurance Requirements
- Fuel Assurance Solutions by Primary Fuel Type
- Testing & Verification Requirements
- Compensation Mechanism
- Implementation Plan
- Solution Packages

Stage 2 Hiatus Work

2020 – 2021

- **Enhanced Restoration Time Analysis**
- Cost / Benefit Analysis Methodology
- Gas Supply Risk Assessment

Stage 3 FRBSR Considerations

2022

- Updated Design Component Details and Solution Packages
- Enhanced Definitions of Fuel Assurance
- Hydro Packages to align with ELCC
- Inputs from FERC/NERC ERCOT Report

Terms

- BSR (Black Start Resource): A generation resource capable of providing black start service during a restoration event

- CL (Critical Load): A generator, nuclear reactor, or electric gas compressor identified in a TO's restoration plan that must be energized by a BSR as part of the restoration process

- FA BSR (Fuel Assured BSR): A Black Start Resource that meets the fuel assurance requirements identified in the table in Slide 4

- NFA BSR (Non-Fuel Assured BSR): A Black Start Resource that does not meet the fuel assurance requirements identified in the table in Slide 4

Post-Hiatus Black Start Fuel Assurance Classification

Classification	Description
Fuel Assured (FA)	Black Start sites that can operate using fuel that is stored on site, this includes oil units and dual fuel units with the capability to start without requiring gas
Fuel Assured (Multiple Pipelines)	Gas only Black Start sites that are connected to more than one interstate natural gas pipeline
Non-Fuel Assured (NFA)	Gas only Black Start sites with one interstate pipeline connection
Non-Fuel Assured (LDC)	Gas only Black Start sites that receive their gas supply via a LDC connection
Non-Fuel Assured (Gas to Start)	Black Start sites that have fuel storage on site but require natural gas for startup ignition
Hydro	Black Start sites that rely on natural river flow to generate electricity or store an inventory of water in an elevated reservoir

Restoration Process

Black Start

- Black start units are brought online without outside power from the system

Critical Load

- Cranking paths from BSRs to CL are developed based on TO restoration plans
- Additional steps, such as picking up load blocks or bringing on other generation, are taken as needed to stabilize the cranking path and island

System Control

- System voltages and frequency need to be controlled to avoid tripping or damaging equipment
- Tripping the restoration island results in having to start the restoration over

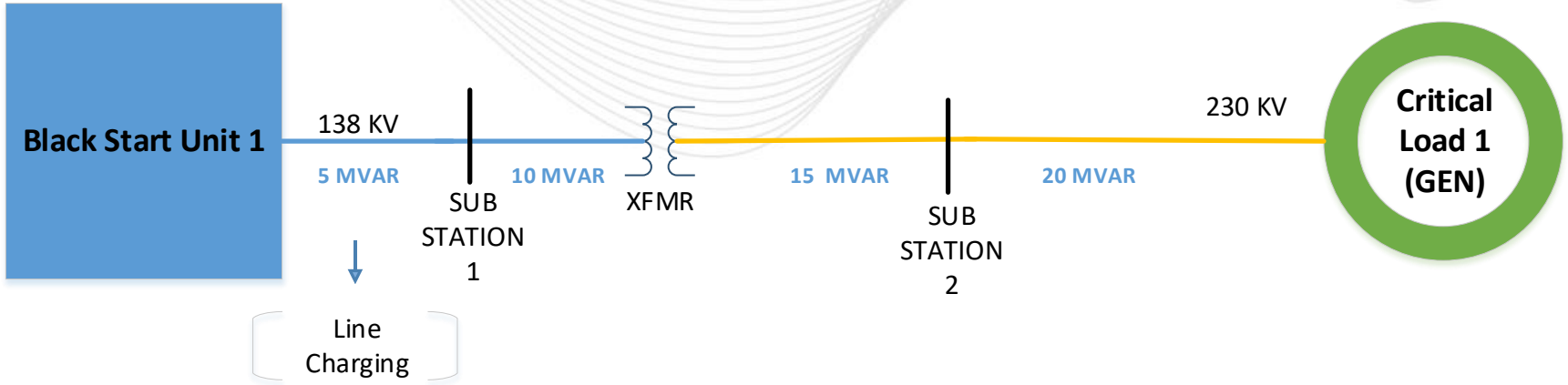
Primary Cranking Path

- Cranking path from a primary BSR to the CL
- Typically the shortest electrical path (least amount of line charging) from BSR to CL
- Shortest electrical path may not have the least number of substations or lines

Alternate Cranking Path

- Cranking path from an alternate BSR to the CL
- Typically require additional generation or load to control voltages which increases restoration times
- Typically have increased line charging & higher line voltages, making them more challenging to build

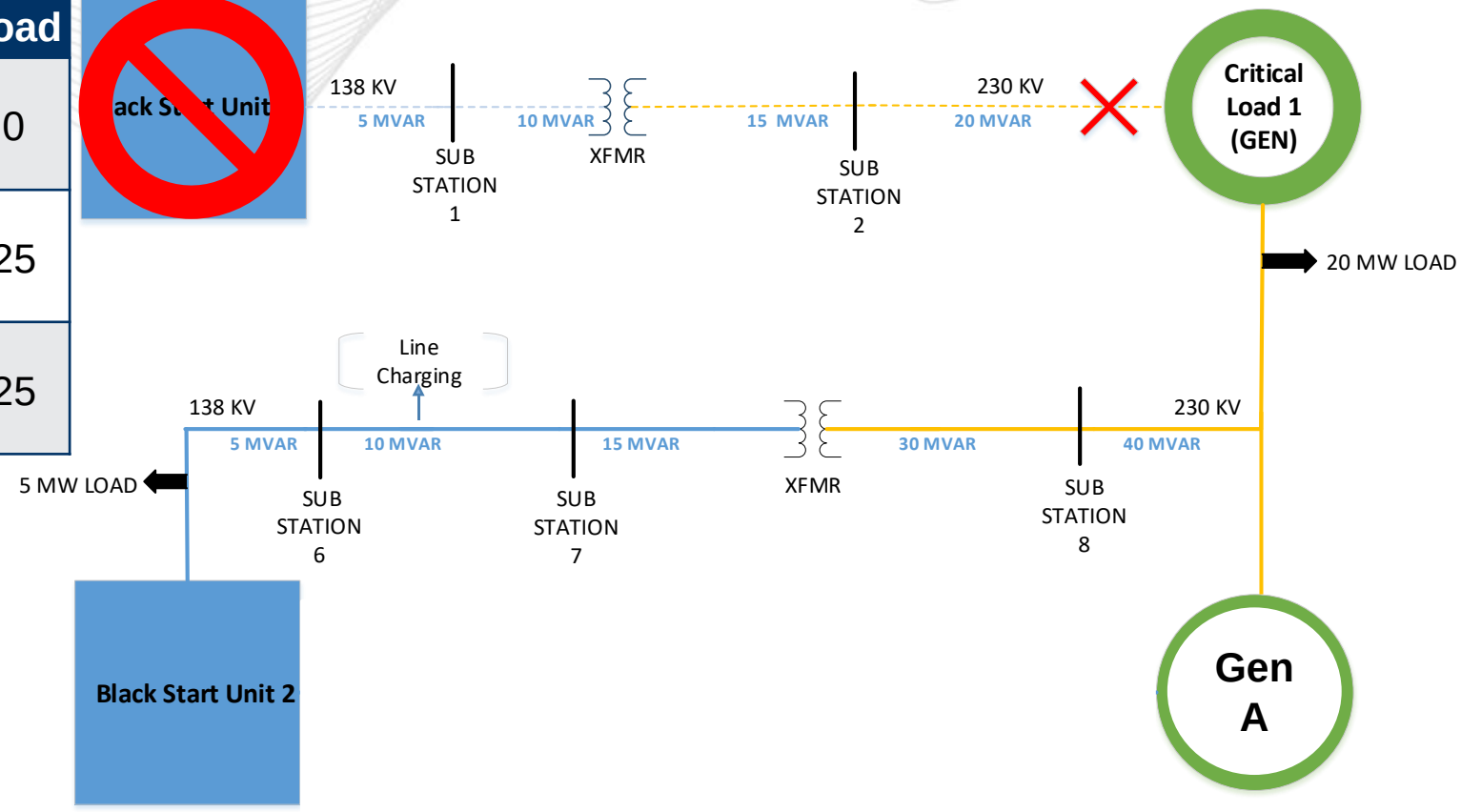
Primary Cranking Path



Cranking Path	Substations	Lines	Generators	Load
Primary Path BS 1 to CL 1	2	4	0	0

Alternate Cranking Path

Cranking Path	Substations	Lines	Generators	Load
Primary Path BS 1 to CL 1	2	4	0	0
Alternate Path BS 2 to CL 1	3	5	1	25
Path Difference	1	1	1	25



In this example, an additional generator and additional load is required to control voltage issues

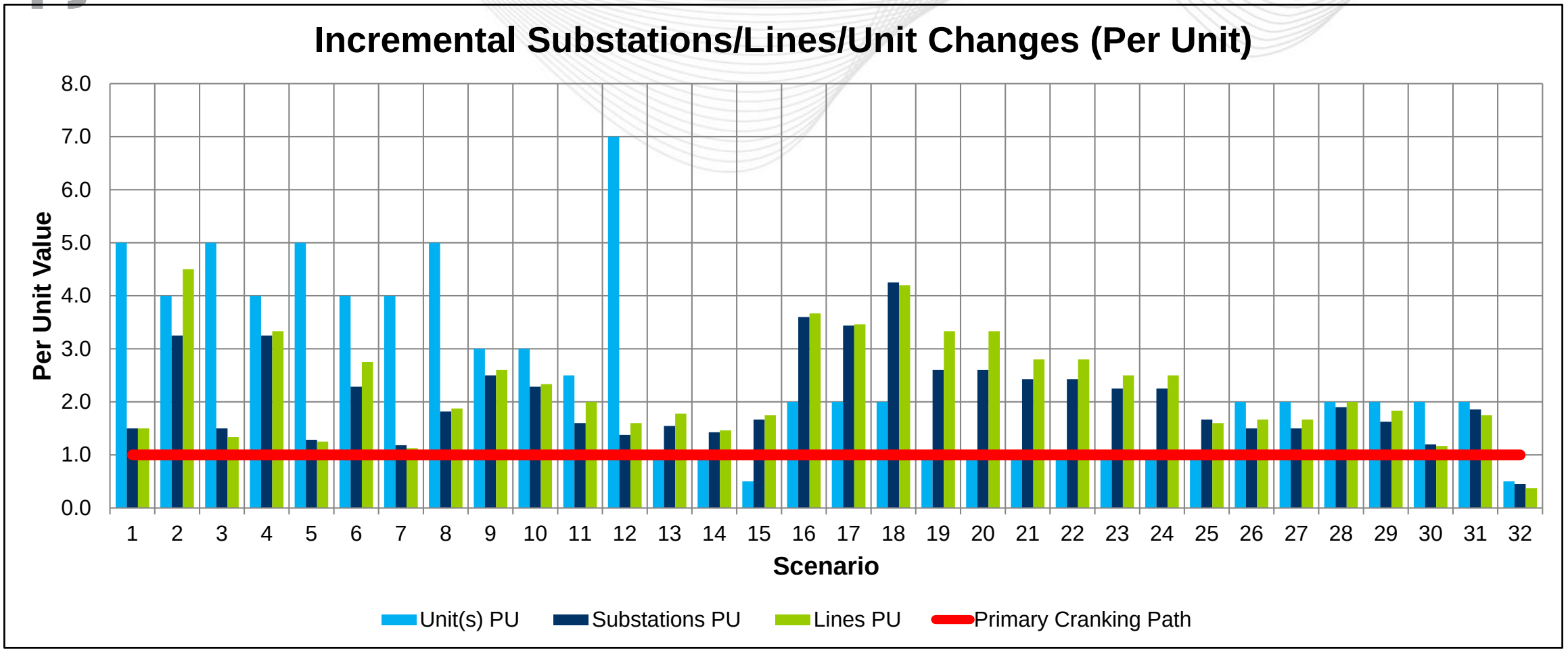
Stage 1 Analysis:
Cranking Path Restoration Timing

Cranking Path Restoration Timing

FRBSR Stage 1 analyzed 32 different Critical Loads that were cranked by a NFA BSR in a sampling of TO zones. An alternate cranking path was developed for each critical load and the complexity of the primary and alternate cranking paths were compared.

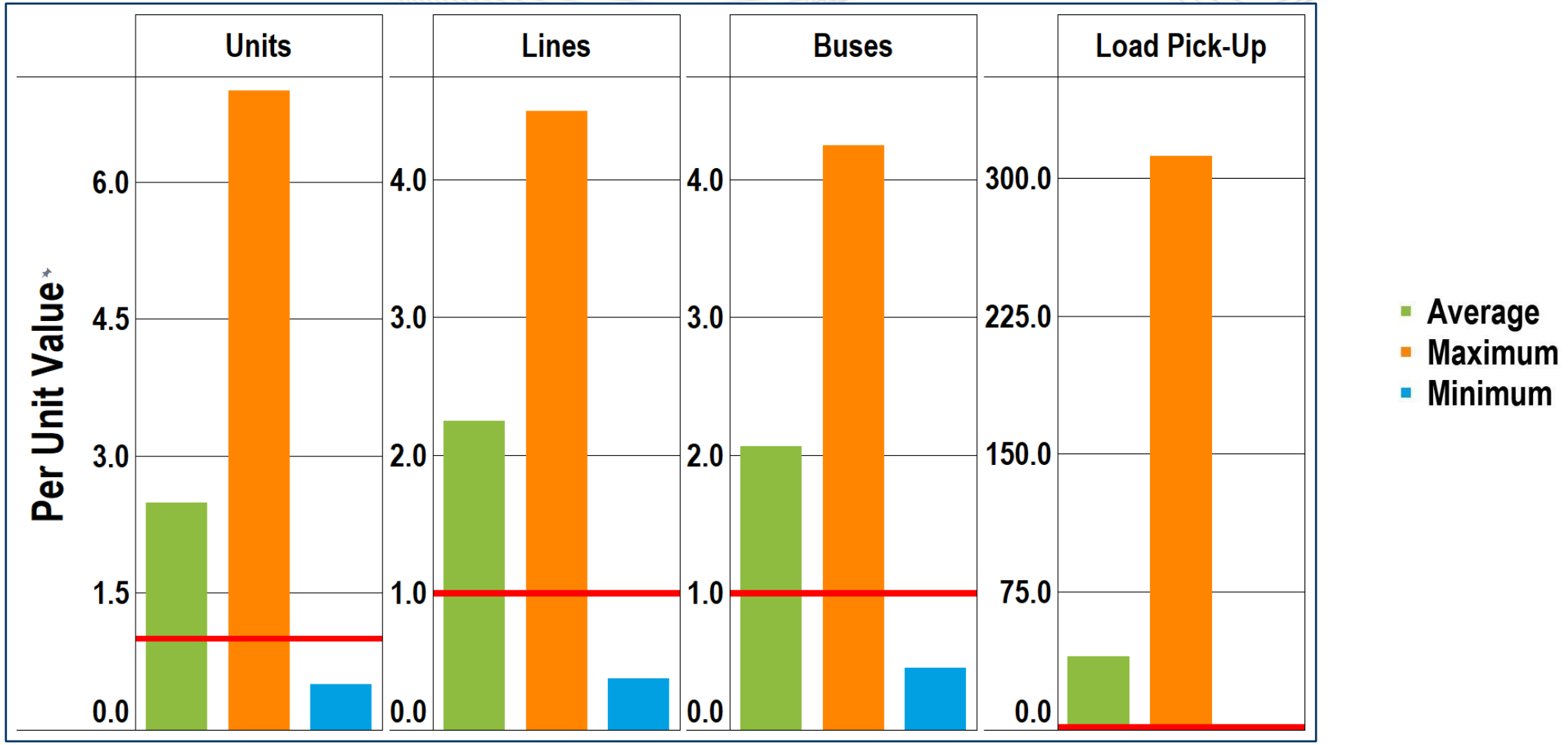
As well as comparing the path complexities, a time estimate for each operational step was developed using input from PJM member TOs. These time estimates were used to quantify the difference between the primary and alternate cranking paths in terms of hours of delay.

Alternate Cranking Path Results



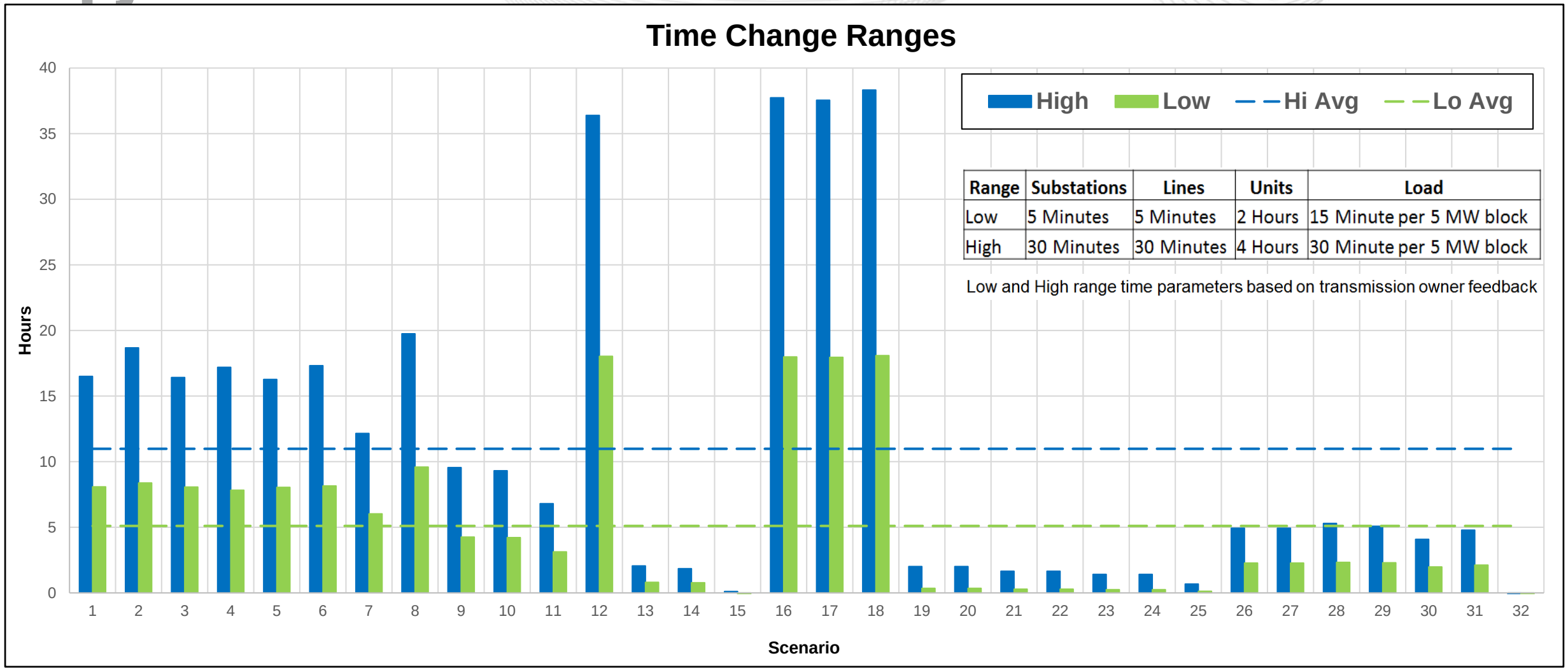
1. Red line represents the required number units or buses or lines needed for primary cranking paths in per unit values
2. Bars indicate the required number of units or buses or lines for alternate cranking paths in per unit values
3. Bars above the red line indicate an increase in the required number of units or buses or lines for alternate cranking paths

Alternate Cranking Path Impacts



Red line represents the number of units, buses, lines or load needed for primary cranking paths in per unit values

Incremental Cranking Path Time Increase



Range	Substations	Lines	Units	Load
Low	5 Minutes	5 Minutes	2 Hours	15 Minute per 5 MW block
High	30 Minutes	30 Minutes	4 Hours	30 Minute per 5 MW block

Low and High range time parameters based on transmission owner feedback

Average time increase per cranking path ranged from 5.1 hours to 10.9 hours, but there were scenarios with high and low range times significantly higher

Stage 1 Analysis Findings

- Almost all alternate paths resulted in increased restoration complexity, which in turn meant an increased time to build the path.
- Approximately 10% of alternate paths failed, primarily due to stability studies, requiring more complex alternate paths.
- The average incremental time increase per cranking path ranged from approximately five hours to eleven hours, but there where some scenarios with significantly higher time ranges
  - Applied to cranking paths across all TO zones with non-fuel assured black start resources, these time ranges could be significant.

Stage 2 (Hiatus) Analysis: Zonal Restoration Timing

Zonal Restoration Timing

In order to perform a more thorough analysis of the impact of BS sites being unavailable on restoration efforts, during the hiatus PJM performed studies at a TO zone level.

This expanded analysis:

- Used the same approach developed in Stage 1
- Studied every cranking path from a NFA BSR in every PJM TO zone with NFA BSRs
- The time range used in Stage 1 was consolidated and just the low time estimate was used in Stage 2

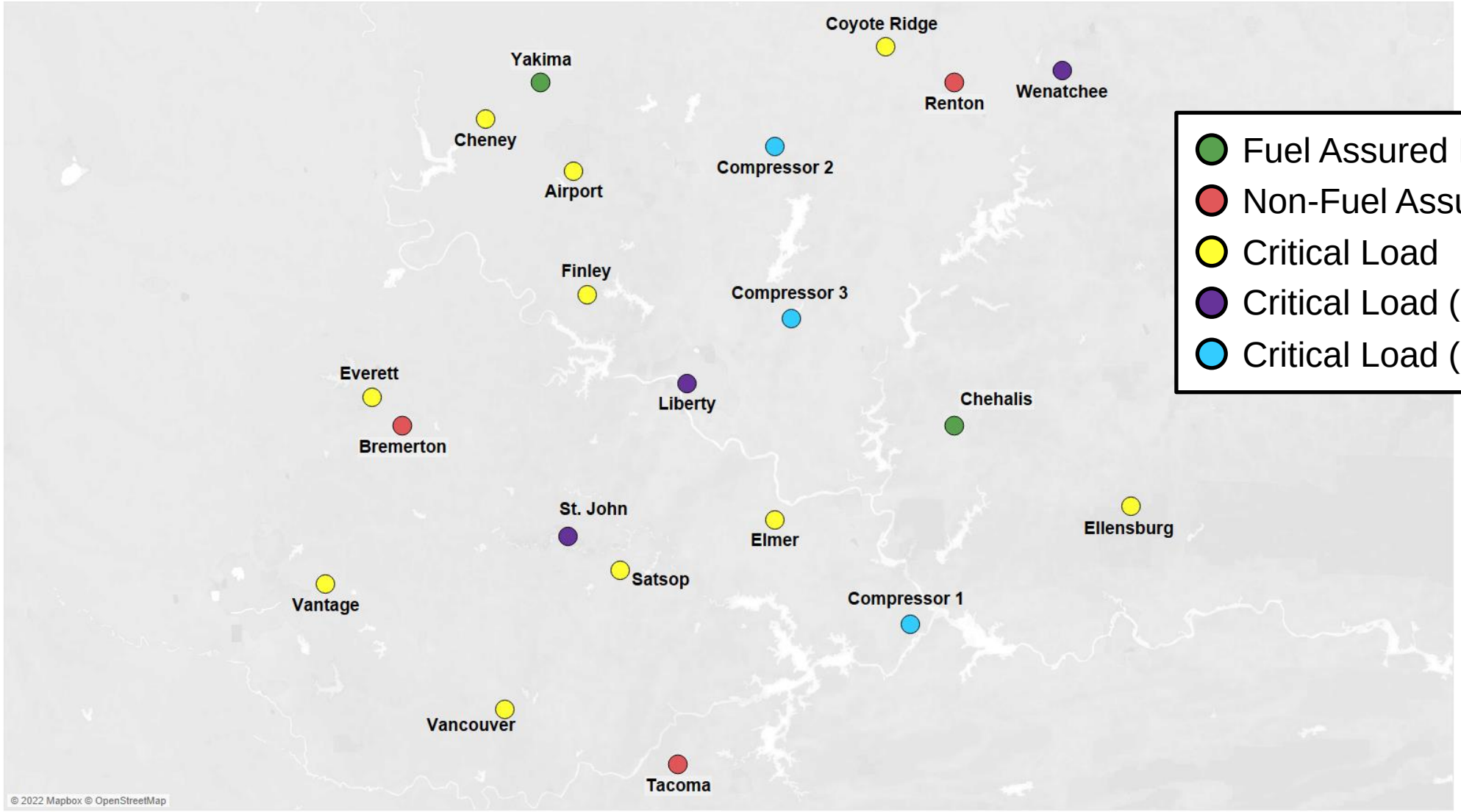
Hypothetical Case: Technical Analysis

As an example, imagine a hypothetical TO zone with eleven Critical Loads that rely on non-fuel assured Black Start resources to be restored.

To analyze this zone:

- Look at multiple restoration scenarios where the various non-fuel assured black start sites are unavailable
- When a BS site is unavailable we identify the next best BSR to crank that Critical Load
- For each scenario we will determine an **incremental restoration time increase** (over and above a typical restoration time) based on this additional restoration complexity

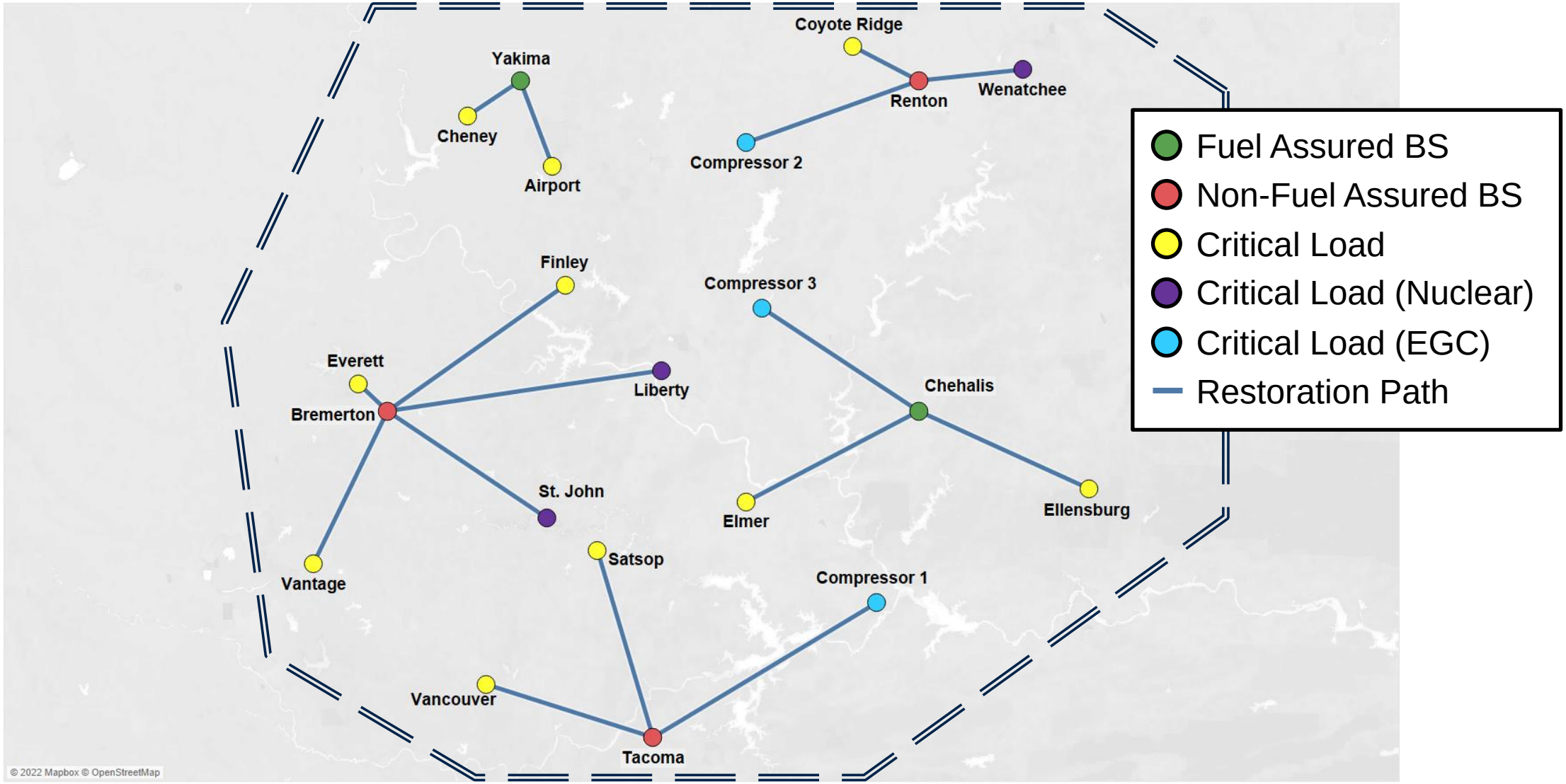
Hypothetical Case: Zonal Layout



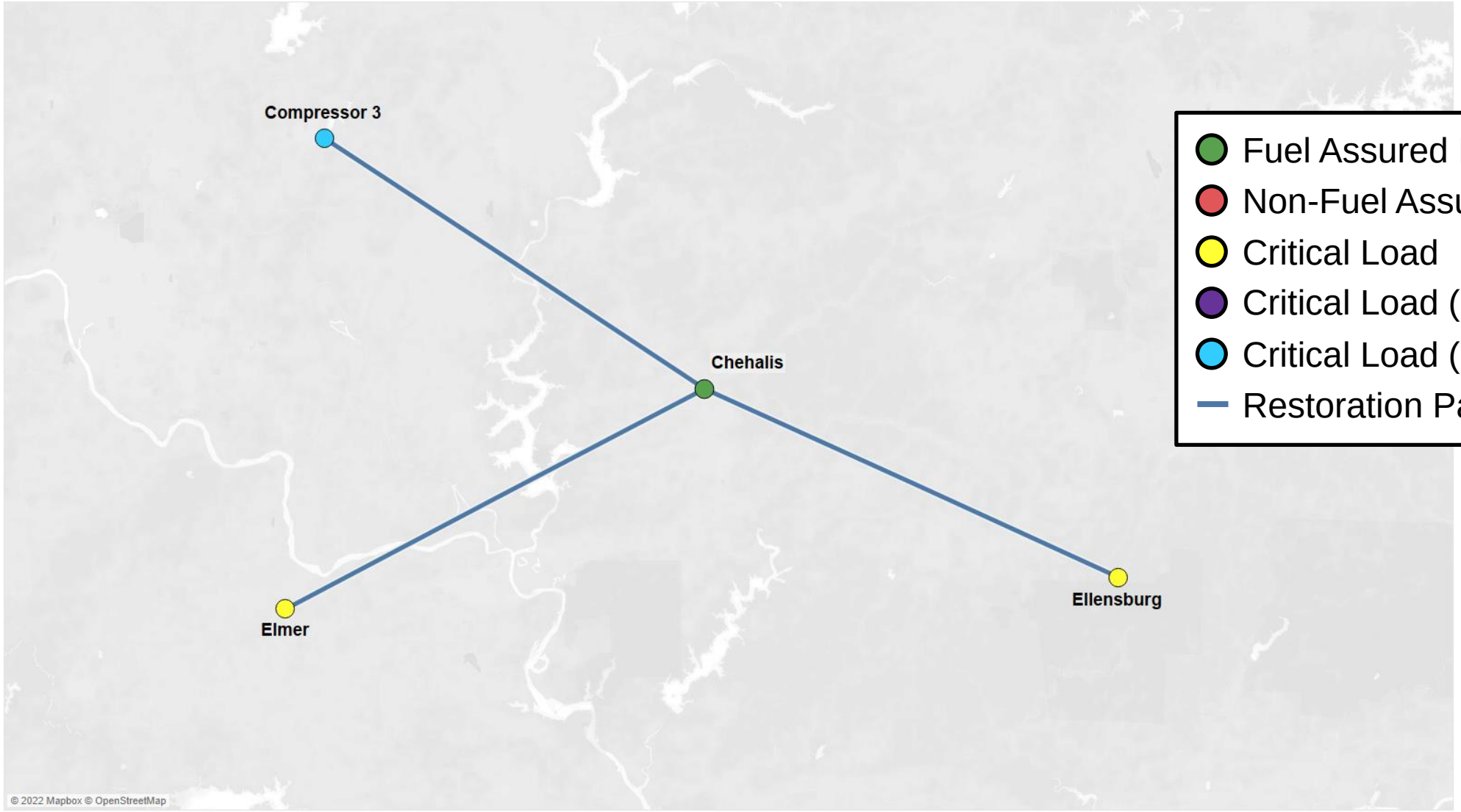
Hypothetical Case: Zonal Sites

Restoration Type		Site
Black Start	Fuel Assured	Chehalis, Yakima
	Non-Fuel Assured	Bremerton, Renton, Tacoma
Critical Load	Generators	Airport, Cheney, Coyote Ridge, Ellensburg, Elmer, Everett, Finley, Satsop, Vancouver, Vantage
	Nuclear	Liberty, St. John, Wenatchee
	Electric Gas Compressors (EGC)	Compressor 1, Compressor 2, Compressor 3

Hypothetical Case: Standard Restoration



Hypothetical Case: Chehalis Island



Hypothetical Case: Chehalis Island Timing

Timing for each path is based on the complexity of each path and accounts for the number of transformers, lines, load blocks, and (potentially) additional generation along the cranking path.

Chehalis → Ellensburg = 90 minutes

Chehalis → Elmer = 180 minutes

Chehalis → Compressor 3 = 120 minutes

Chehalis Island = 90 + 180 + 120 = 390 minutes = **6.5 hours**

Hypothetical Case: Zonal Timing

While each black start site can only crank one critical load at a time, it's possible for each island to be built in parallel because they are independent of each other. The overall zonal restoration time is then equal to the slowest island time.

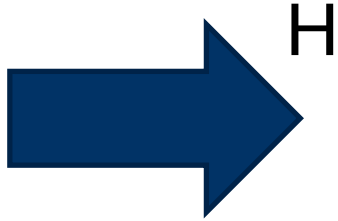
Bremerton Island: 9.0 Hours

Chehalis Island: 6.5 Hours

Renton Island: 6.0 Hours

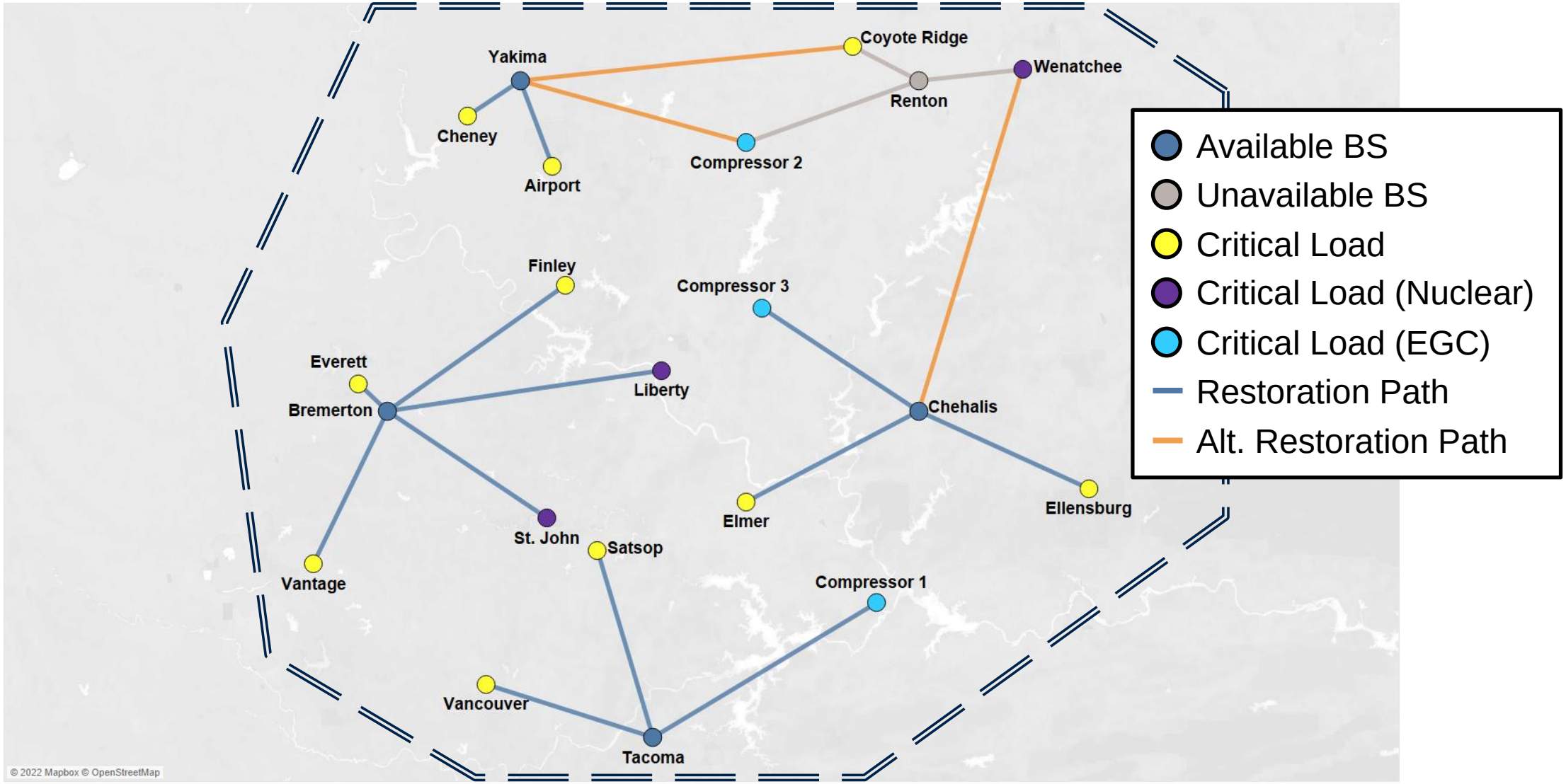
Tacoma Island: 8.0 Hours

Yakima Island: 5.5 Hours



Hypothetical Zonal Restoration Time: **9.0 Hours**

Hypothetical Case: Scenario 1
Loss of Renton



Hypothetical Case: Scenario 1
Loss of Renton Timing

To account for the loss of Renton in a restoration, alternate black start sites must crank those critical loads in addition to what they normally crank.

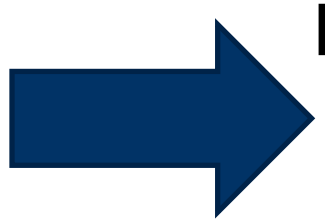
Bremerton Island: 9.0 Hours

Chehalis Island: 6.5 + **5.0** = **11.5** Hours

Renton Island: **N/A**

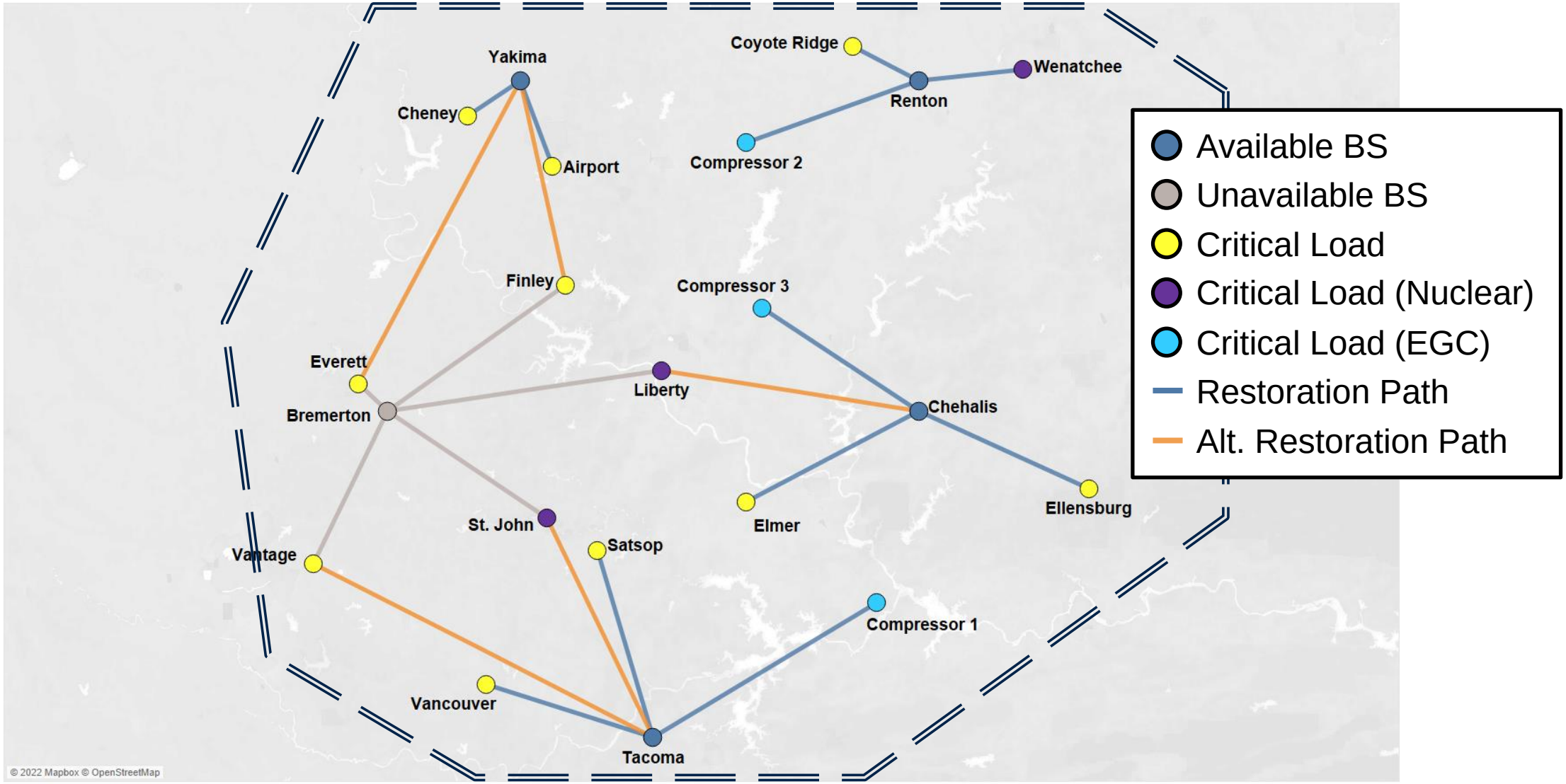
Tacoma Island: 8.0 Hours

Yakima Island: 5.5 + **1.5** + **2.0** = **9.0** Hours



Hypothetical Zonal Restoration Time: **11.5 Hours**

Hypothetical Case: Scenario 2
Loss of Bremerton



Hypothetical Case: Scenario 2
Loss of Bremerton Timing

To account for the loss of Bremerton in a restoration, alternate black start sites must crank those critical loads in addition to what they normally crank.

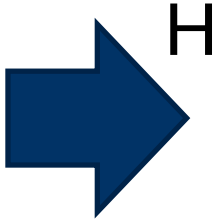
Bremerton Island: **N/A**

Chehalis Island: 6.5 + **2.0** = **8.5** Hours

Renton Island: 6.0 Hours

Tacoma Island: 8.0 + **6.0** + **5.5** = **19.5** Hours

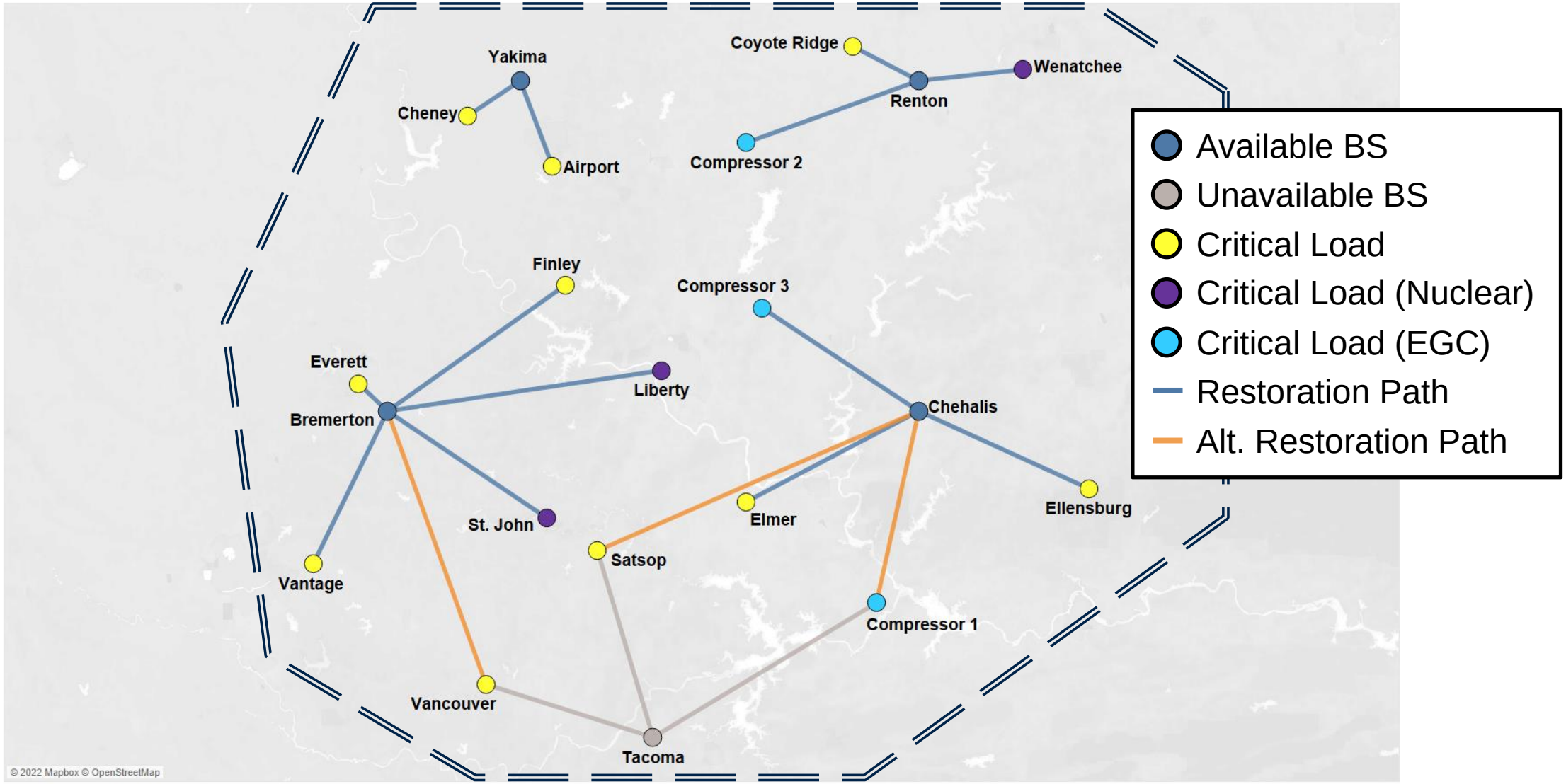
Yakima Island: 5.5 + **4.5** + **2.0** = **11.0** Hours



Hypothetical Zonal Restoration: **19.5 Hours**

Time

Hypothetical Case: Scenario 3
Loss of Tacoma



Hypothetical Case: Scenario 3
Loss of Tacoma Timing

To account for the loss of Tacoma in a restoration, alternate black start sites must crank those critical loads in addition to what they normally crank.

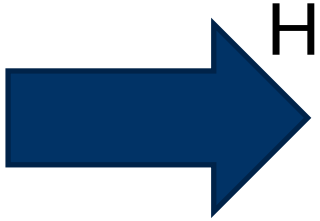
Bremerton Island: 9.0 + **5.5** = **14.5** Hours

Chehalis Island: 6.5 + **4.5** + **5.0** = **10.0** Hours

Renton Island: 6.0 Hours

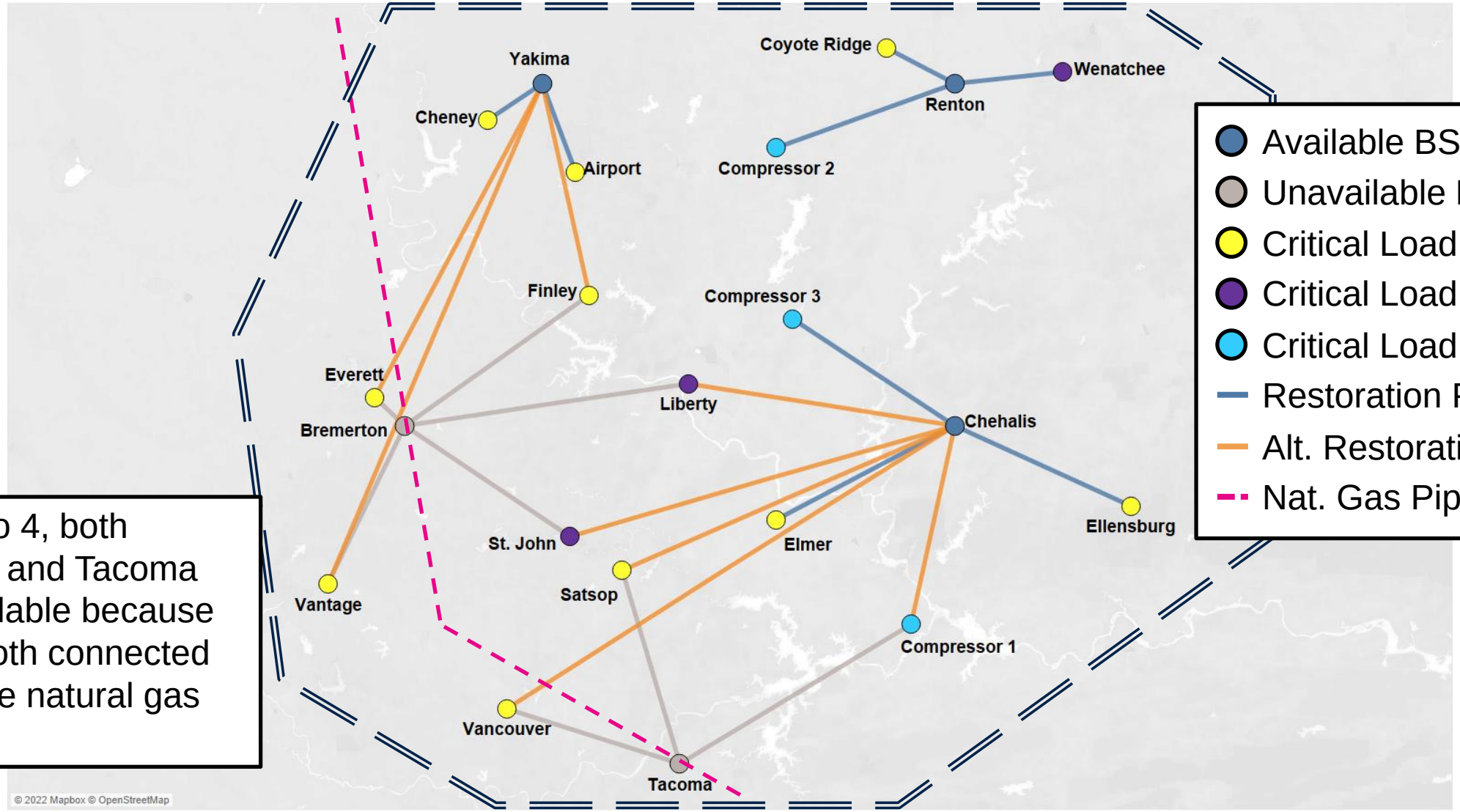
Tacoma Island: 8.0 Hours

Yakima Island: 5.5 = 5.5 Hours



Hypothetical Zonal Restoration Time: **14.5 Hours**

Hypothetical Case: Scenario 4
Loss of Bremerton and Tacoma



In Scenario 4, both Bremerton and Tacoma are unavailable because they are both connected to the same natural gas pipeline

Hypothetical Case: Scenario 4
Loss of Bremerton and Tacoma Timing

To account for the loss of Bremerton and Tacoma in a restoration, alternate black start sites must crank those critical loads in addition to what they normally crank.

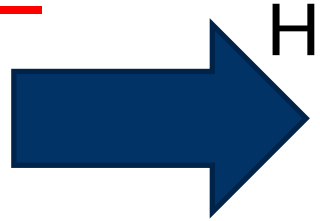
Bremerton Island: **N/A**

Chehalis Island: 6.5 + **2.0** + **4.5** + **5.0** + **5.5** + **9.0** = **32.5** Hours

Renton Island: 6.0 Hours

Tacoma Island: **N/A**

Yakima Island: 5.5 + **4.5** + **2.0** + **8.5** = **20.5** Hours



Hypothetical Zonal Restoration: **32.5 Hours** Time

Hypothetical Case: Timing Comparison and High Impact Black Start Sites

Scenario	Hypothetical Zonal Restoration Time	Incremental Restoration Time Increase
Standard Restoration	9.0 Hours	
Scenario 1: Loss of Renton	11.5 Hours	2.5 Hours
Scenario 2: Loss of Bremerton	19.5 Hours	**10.5 Hours**
Scenario 3: Loss of Tacoma	14.5 Hours	5.5 Hours
Scenario 4: Loss of Bremerton & Tacoma	32.5 Hours	**23.5 Hours**

Incremental Restoration Time Increase: Additional time required to restore a TO zone due to the loss of one or more BS sites above and beyond the theoretical zonal restoration time with all BS sites available.

High Impact Black Start Site: A BS site which, when unavailable during a restoration scenario, results in an incremental restoration time increase of ten hours or more. This ten hour cutoff is a PJM suggestion and not tied directly to any standards.

Hiatus Analysis Work

During the hiatus period, PJM performed this level of analysis for all PJM TO zones with NFA BSRs and all BSR site availability scenarios within those zones.

The scenarios studied were based on the idea of a single contingency affecting the BS availability within that zone (N-1). As additional simultaneous contingencies are studied (N-1-1), the incremental restoration time increase goes up dramatically.

Zonal Restoration Timing Verification

PJM worked with a member TO, with EPRI to perform and independent assessment of the analysis methodology

- A member TO worked with EPRI to perform similar evaluations
- With the support of EPRI, the member TO used the EPRI System Restoration Navigator (SRN) tool to study the cranking paths within their zone

The TO study:

- Confirmed the PJM approach worked and provided very similar results
- Slight differences arose from variations in cranking paths used

Summary

Performing this analysis at a zonal level (Hiatus Analysis) as opposed to looking at individual cranking paths independently (Stage 1 Analysis) provides a much more complete assessment of the possible delays to restoration efforts.

This analysis quantitatively evaluates the impact of performing a zonal bottom-up restoration with NFA BS sites unavailable, and can provide inputs to a cost / benefit analysis.

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Fuel Requirements for Black Start Resources