Pacific Northwest
NATIONAL LABORATORY

PNNL Resilient Ports Project

Supporting Resilient Electric Supply at Maritime Ports

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U.S. DEPARTMENT OF ENERGY BATTELLE

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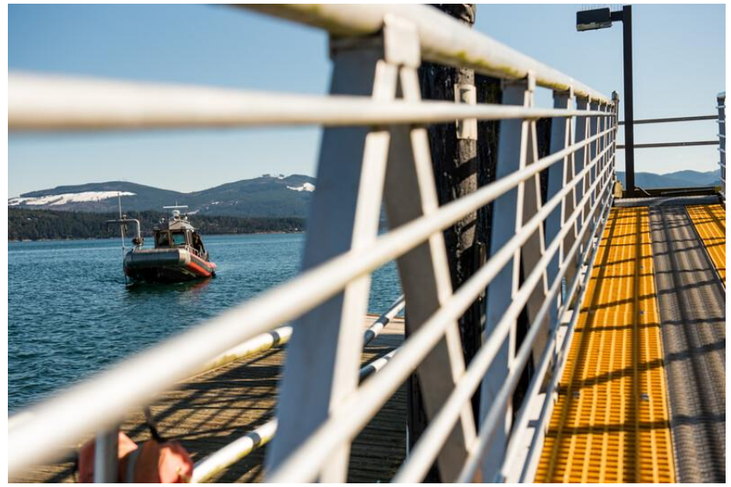
Maritime Decarbonization at PNNL

Mission Statement: We transform the world through courageous discovery and innovation.

- PNNL is a U.S. Department of Energy (DOE) Office of Science National Laboratory with core capabilities including chemical and material sciences, engineering, biological and earth sciences.
- PNNL manages the DOE's only coastal science lab in Sequim, WA.
- Maritime decarbonization is a cross-cutting effort across various divisions at PNNL including Coastal Sciences and Energy, Buildings & Infrastructure.
- This work aligns with our lab's objective to Decarbonize End Uses and with the federal Ocean Climate Action Plan (2023).
- Key projects include:
  - The Port Electrification Handbook
  - Green Corridors Grid Impact Analysis
  - RV Resilience – Hybrid Electric Vessel



Why Electrify Ports?

- **Resilience** – Cargo activities at US seaports generate over $5T in economic activity, equal to 26% of the U.S. economy [1]. They are also gateways to critical supplies, particularly in the case of a natural disasters.
- **Climate** – Maritime activities account for 3% of global carbon emissions [2], roughly equivalent to the annual emissions of Germany.
- **Environmental Justice** – PM emissions from shipping are responsible for approximately 60,000 premature deaths annually [3].
- **Energy Independence** – Electrification, coupled with renewable generation and storage (e.g., microgrids), can provide localized energy to ports and benefit national security.

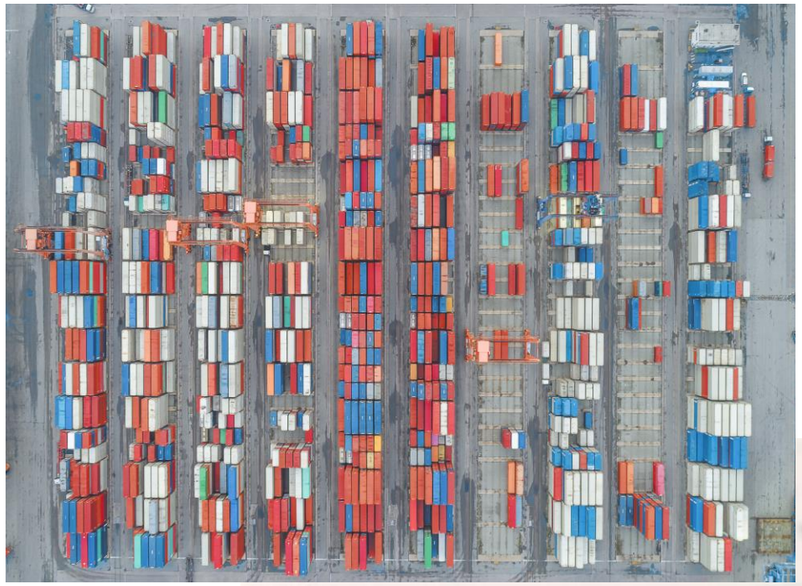
[1] American Association of Port Authorities

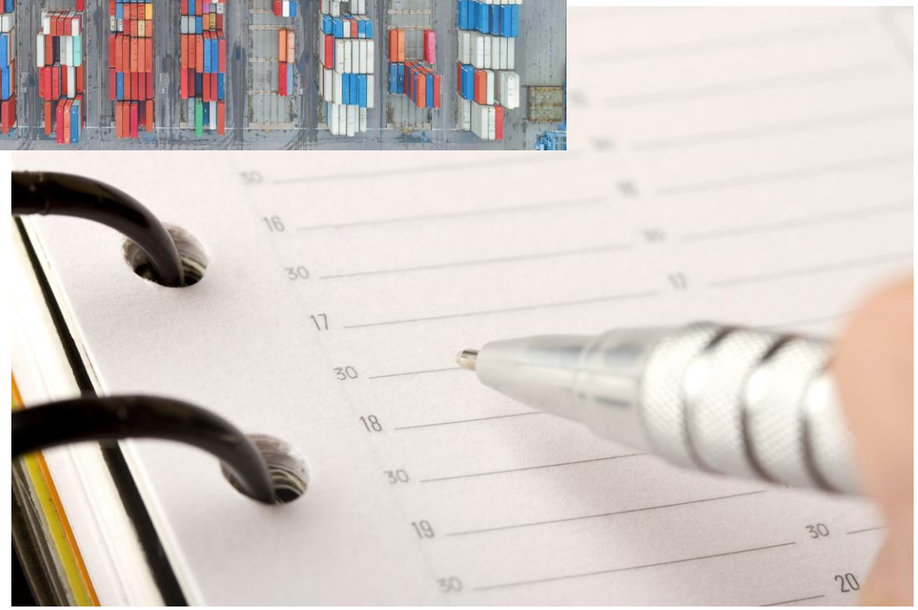
[2] International Council on Clean Transportation: Maritime Shipping

[3] Rutherford et al. 2019 “Silent but Deadly: The Case of Shipping Emissions”

Resilient Ports Project

- The objective of this effort is to support the resilient decarbonization of the nation's electrical infrastructure leveraging networked microgrid technologies. Maritime ports are used as an operational use-case because of their size, complexity, and resource mix.
- The outcome broadly includes two efforts:
  - **Resilient Microgrids Case Study** – Seattle City Light (complete)
  - **Port Electrification Handbook** (expected completion Feb 2024)





Resilient Microgrids Case Study

Based loosely on the Port of Seattle

Port Background:

- Deepwater port critical to regional economy
- Leading electrification and plans to expand
- Constrained by space and utility capacity

Project Overview:

- Evaluated 7 microgrid scenarios
- Analysis from an electrical and dynamic stability perspective
- Assumed ideal scenarios (e.g., required permissions are in–place)

DERs	Notes
PV - Aquarium	Planned since 2023
BESS	Plug-in hybrid ferry charging
EVCS	LDV, MDV, HDV charging, cargo handling equipment
Biodiesel Generator	Generation backup
Hydrogen	Generation and storage - local and shipboard

Image Source: https://www.portseattle.org/cruise-ships

Electric Loads	Notes
Aquarium (existing)	May need critical power
Coast Guard (existing)	Critical load during disaster operations
Ferries (future)	Estimated plug-in hybrid ferry charging load
Fire Station (existing)	Critical load during disaster operations
Cruise (future)	“Cold-ironing” of cruise ships
STS Cranes (existing)	Electrified ship to shore cranes
Refrigerated Units (existing)	Electrified containerized refrigeration units

Microgrids 101

- **Microgrid** – a self-contained power grid that can operate independently or connected to a utility grid.
- Microgrids typically contain:
  - Distributed Energy Resources
  - Energy Storage
  - Distribution Infrastructure
  - Microgrid Controller

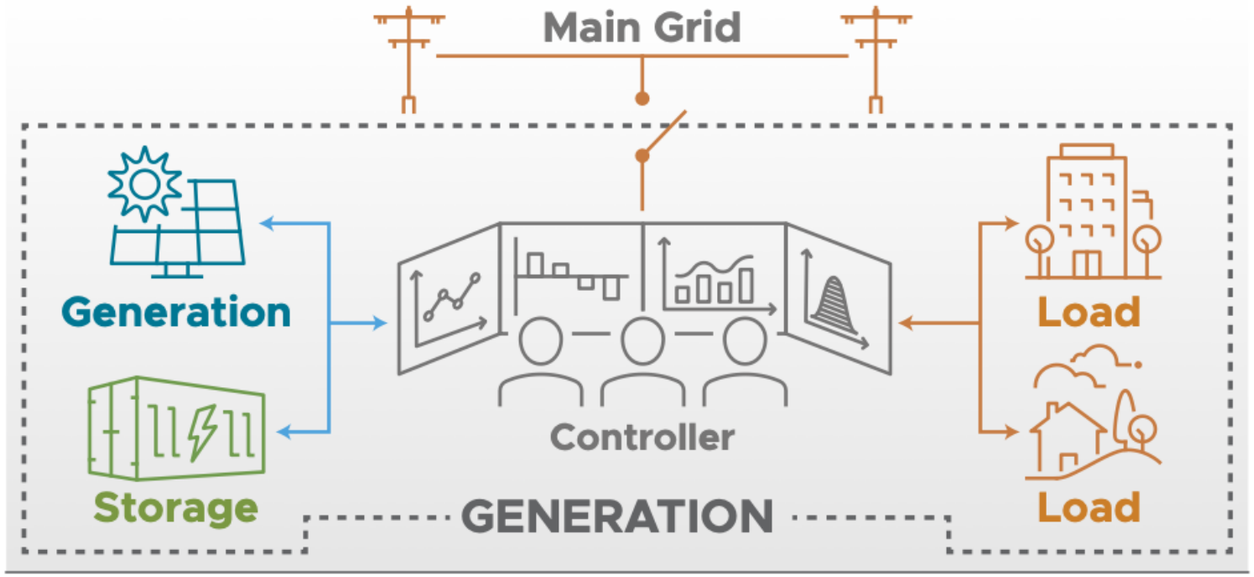
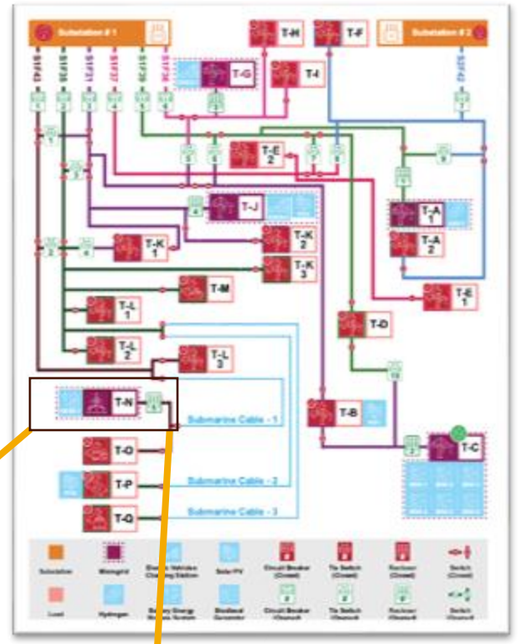


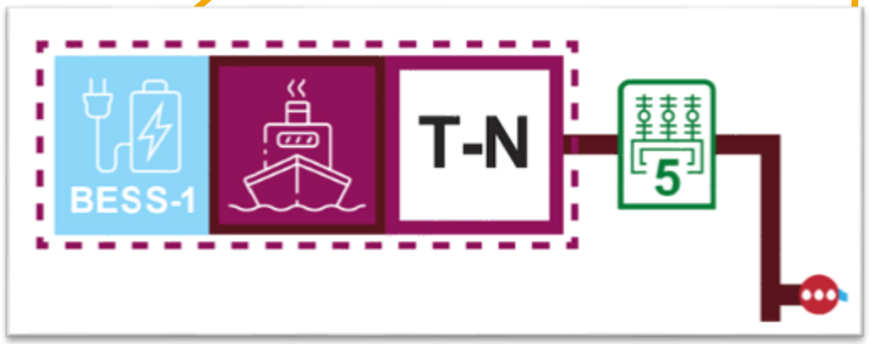
Figure 1. Microgrid components (dashed box) and switch connection to the main grid (top)

Figure 2. Example components of a microgrid

Standard Microgrid Scenario

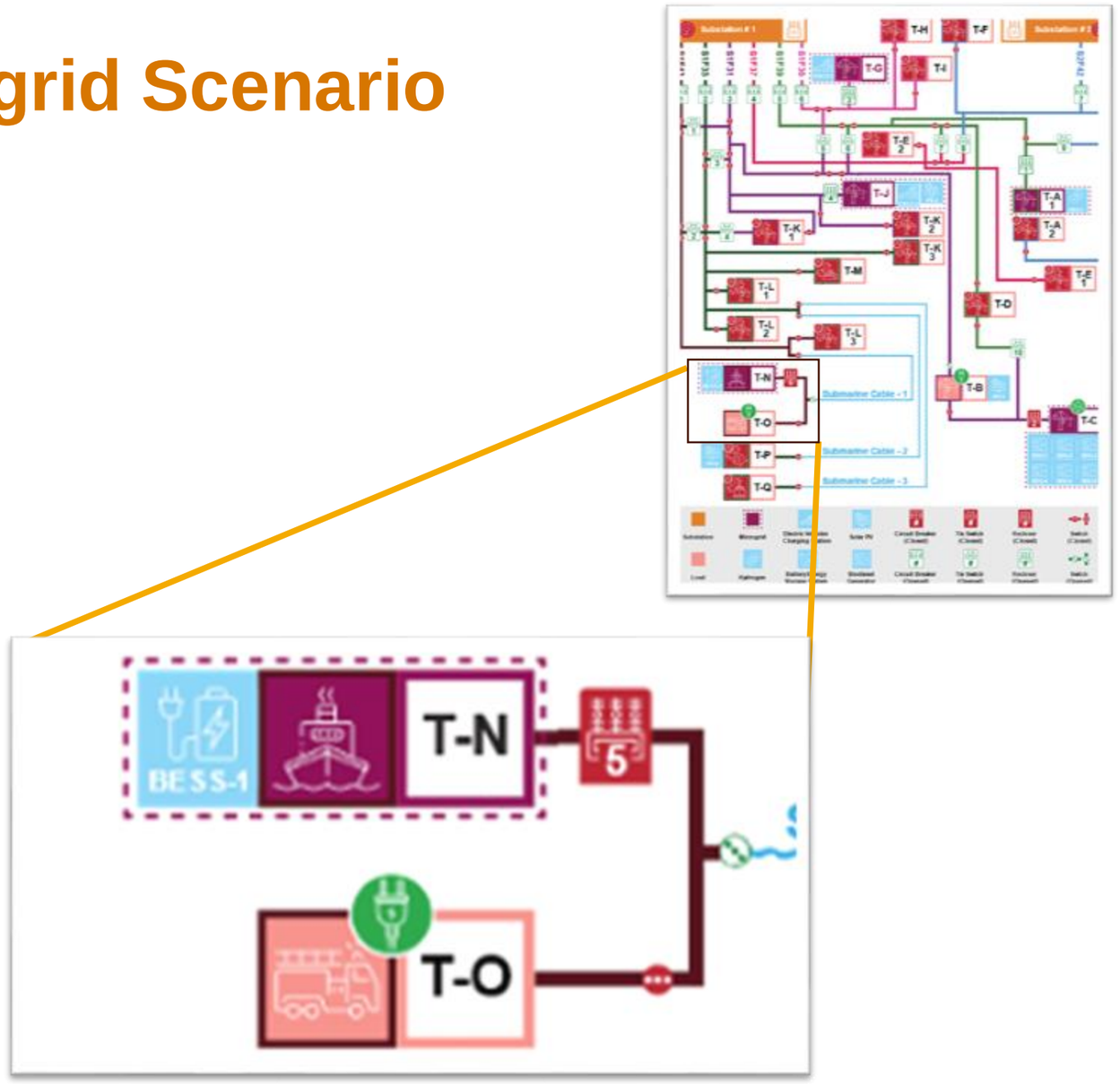
- **Loss of both substations → 5 independent microgrids**
- Microgrids are primarily engaged in a resilience scenario:
  - Solar and hydrogen powering critical port operations
  - Battery powering limited ferry charging
- Reflects traditional microgrids operations that enable capabilities in a resilience scenario without sharing or redundancy in operations
- Each microgrid is limited by its energy storage and generation capabilities (e.g., ferry charging available until BESS is depleted)





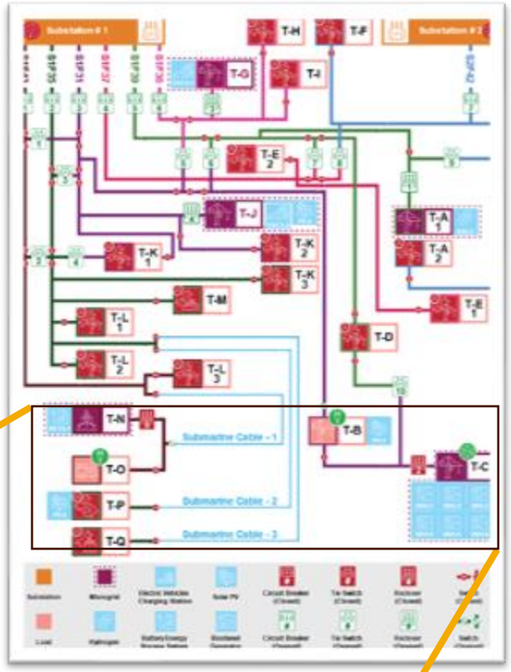
Community Microgrid Scenario

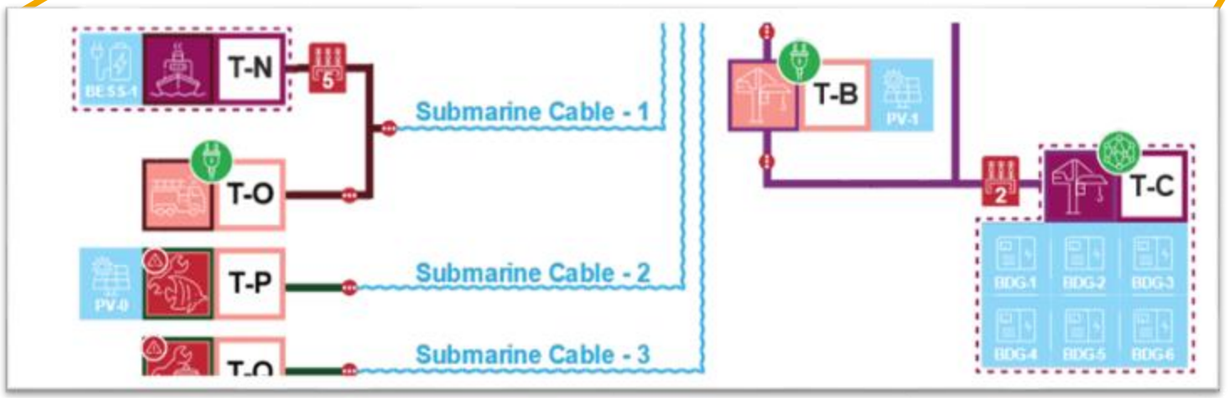
- **Community microgrid** – a microgrid that can utilize non-microgrid distribution infrastructure to power select infrastructure, particularly in critical scenarios
- In this example, a community microgrid extends battery power that is typically reserved for ferry charging to the fire station
- Utility coordination is key as utility distribution lines and switchgear are used



Networked Microgrids Scenario

- **Networked microgrids** – a group of microgrids that are physically separate but interoperable, can share loads and generation across boundaries
- Networking between ferry microgrid and cargo handling equipment microgrid enables BESS charging from biodiesel generators to charge ferry
- Integrating PV can power critical operations and charge BESS
- Utility coordination is key as utility distribution lines and switchgear are used





Port Benefits of Microgrids

- **Resiliency:**
  - Power critical infrastructure during bulk power system outage
  - Increase redundancy of power availability
  - Enhance port energy independence
- **Economics:**
  - Provide flexibility to integrate cost effective energy solutions
  - Enable participation in available energy markets
  - Avoid high costs of power outages
- **Climate:**
  - Decrease emissions by integrating renewables and generators powered by cleaner fuels
  - Integrate DERs to support new electrical loads

Port Electrification Handbook

- **Goal:** Develop a reference to aid ports in their clean energy transition.
- **Timeline:** Currently in-development, planned completion February 2024.
- As outlined currently, handbook topics include:
  - Port Electrification Overview
  - Microgrids
  - Electrification technologies (e.g., shore power, charging infrastructure)
  - Alternative fuel vehicles, vessels, and associated supportive infrastructure
  - Port renewable energy options including solar, wind, and marine energy
  - Planning and design considerations
  - Addressing cybersecurity and resiliency in port energy transitions
  - Case studies and technoeconomic analysis
- We are currently conducting outreach and soliciting feedback from Ports and maritime professionals via 1x1 meetings, Guiding Port Partners, and a survey.

Port Survey

Questions?

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