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Port Electrification Handbook

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U.S. DEPARTMENT OF ENERGY BATTELLE

PNNL is operated by Battelle for the U.S. Department of Energy

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DOE's 17 **national laboratories** address critical scientific challenges

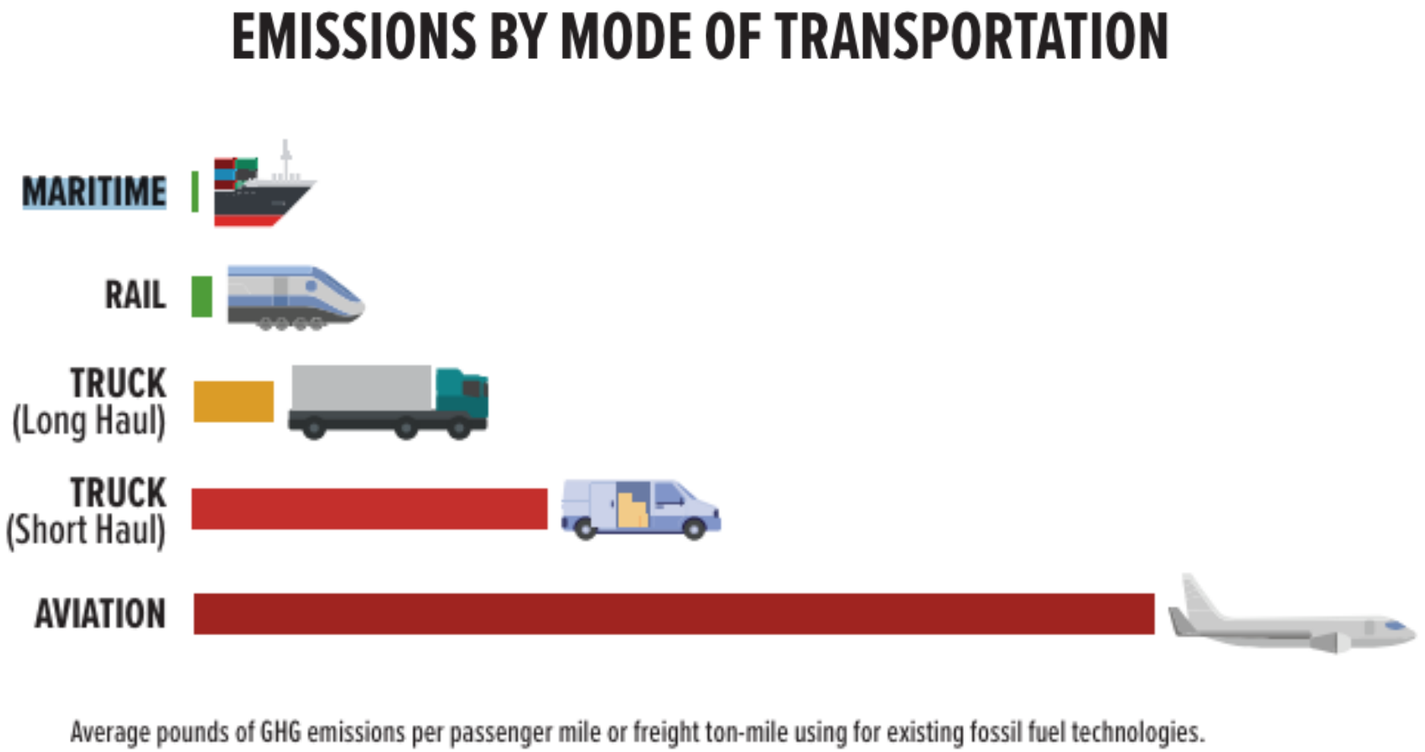
Why Decarbonize the Maritime Sector?

Maritime

- Most efficient
- Projected increase

But:

- 3% of GHG
- Disproportionate impact



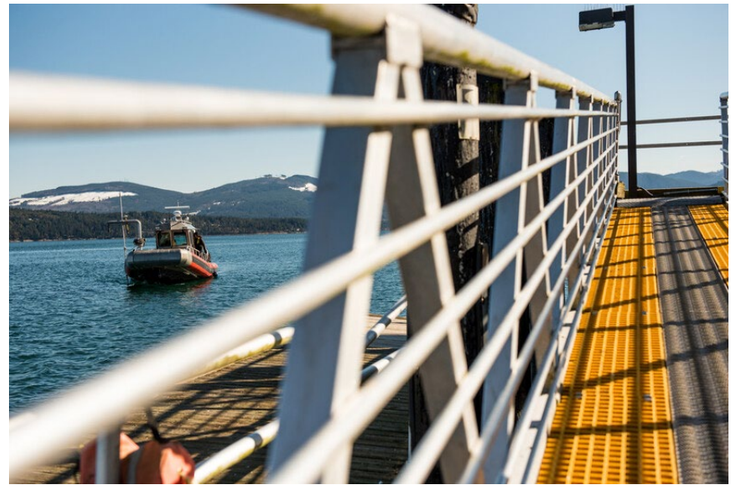
Source: The U.S. National Blueprint for Transportation Decarbonization

Significant federal funding for transportation decarbonization can be leveraged for ports infrastructure and energy transitioning (e.g., EPA, MARAD, DOE).

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



Port Electrification Technologies

Electric Cargo Handling Equipment

Image: Electric Rubber Tire Gantry Crane (eRTG) [1]

- Electric/hybrid vessel charging
- Refrigerated container units

Vessel Shore Power

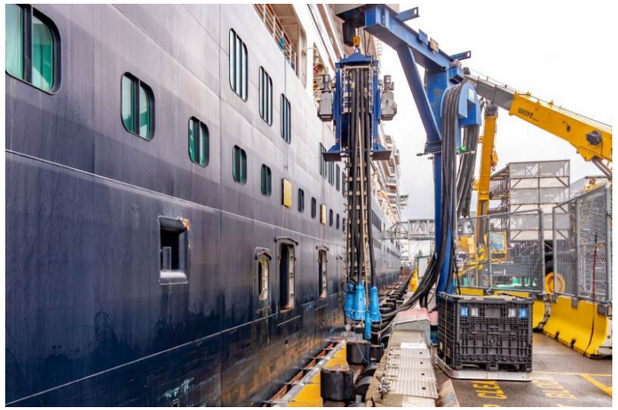


Image: Shore power connection at Port of Seattle [2]

- Rail (e.g., switch locomotive)
- Buildings

MD/HD Vehicle Charging

Image: Truck charging depot at Port of Long Beach [3]

- Workplace vehicle charging
- Fleet vehicle charging

[1] https://www.vahleinc.com/ertg-cranes.html
[2] https://www.portseattle.org/blog/past-present-and-future-shore-power
[3] https://www.freightwaves.com/news/wattev-opens-public-truck-charging-depot-in-long-beach-port

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BENEFITS OF PORT ELECTRIFICATION

Environmental
- Air Quality
- Environmental Justice
- Water Quality
- Noise Reduction

Economic
- Potential Cost Savings
- Economic Growth Potential
- Innovation & Technological Adv.
- Regulatory Compliance

Resiliency
- Resilient Critical Infrastructure
- Energy Independence
- National Security

POTENTIAL CHALLENGES FACING PORT ELECTRIFICATION

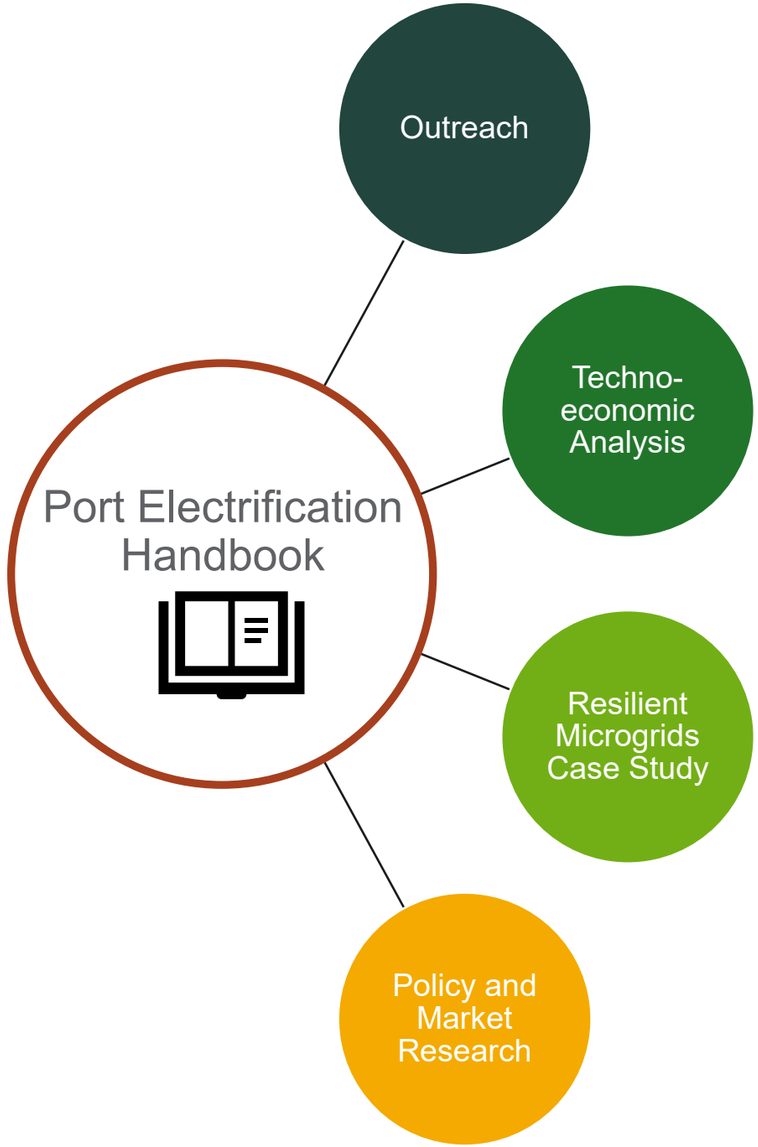
Technology Challenges
- Equipment Availability
- Equipment Costs
- Operational Requirements

Electrical Challenges
- Electrical Infrastructure Requirements
- Electrical Supply
- Utility Coordination

Implementation Challenges
- Multi-stakeholder Landscape
- Labor Relations
- Regulatory Complexity
- Business Impacts

Port Electrification Handbook

- **Goal:** A step-by-step guide and reference to aid ports in electrification.
- **Guiding Port Partners:**
  - Northwest Seaport Alliance
  - Port of Anacortes
  - Port of Bellingham
  - Port of Detroit
  - Port of Long Beach
  - Port of Los Angeles
  - Port of Seattle
- **Related Work:**
  - Port Electrification Toolkit (SNL)
  - Vehicle Technologies Office Non-Road Decarbonization Project (ANL, LBNL, SNL, PNNL)
  - Green Corridors Grid Impacts Analysis (PNNL, NREL, ORNL)
- **Desired Impact:**
  - Go-to resource for ports and planners
  - Share publicly available tools and data
  - Help inform applications for future funding
- **Funded by DOE Office of Electricity**



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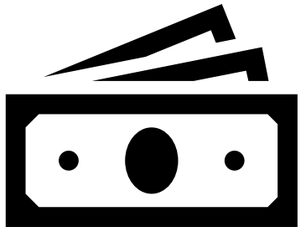
Port Electrification Handbook Topics

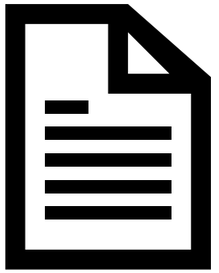


Making the business case for electrification

- Technoeconomic analysis
- Funding opportunities
- Use case examples

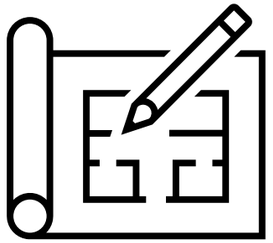
Port Decarbonization Landscape

- Stakeholder mapping
- Utility coordination
- Electrification vs. alternative fuels



Publicly Available Resources

- Lab-developed tools
- Supporting data
- Further reading



Planning Guidance

- Process suggestions
- Opportunities by port-type
- Resiliency considerations

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

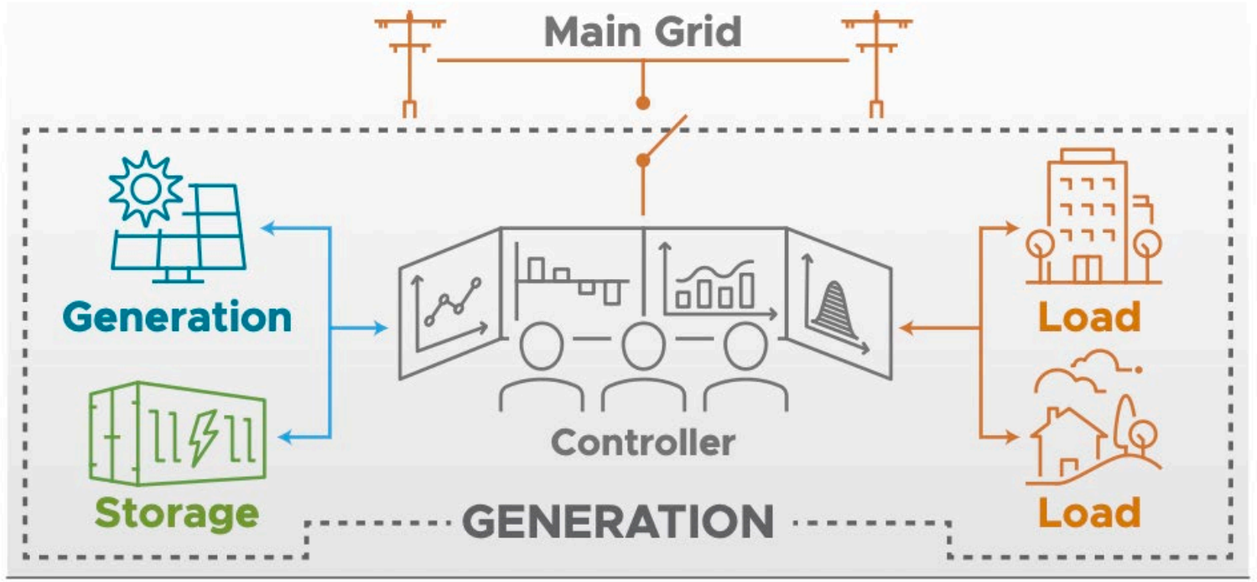
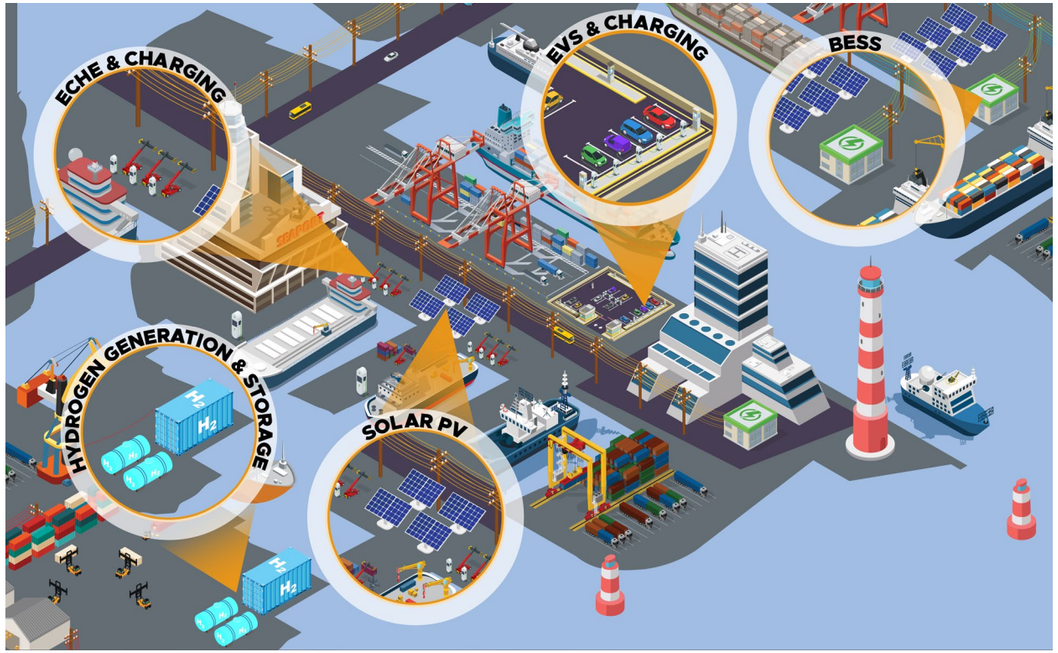


Figure 1. Microgrid components (dashed box) and switch connection to the main grid (top)

Figure 2. Example components of a microgrid

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



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Electrification Technology Readiness

RESEARCH & DEVELOPMENT	PILOTS UNDERWAY/ LIMITED DEPLOYMENTS	WIDELY AVAILABLE & ADOPTED
Networked Microgrid	Community Microgrid	
	Single Port Microgrid	
Marine Energy	Vehicle-to-Grid Connection	Combustion-Based Generation
Hydrogen Generation & Storage	Distributed Wind	Battery Energy Storage System
Small Modular Reactor		Solar/Photovoltaic
On-Port Fuel Production	Electric Cargo Handling Equipment*	Vessel Shore Power (Low-Voltage)
	Emission Control Systems	Electric Ship to Shore Crane
	Electric & Hybrid Vessel Charging	Light-Duty EV Charging
	Medium- & Heavy-Duty EV Charging	Electric Heating and Air
	Rail	Refrigerated Container Units
	Vessel Shore Power (High-Voltage)	Electric Forklift (Class 1-3)

** Electric Cargo Handling Equipment is a diverse category where many technologies are under pilots and limited deployments (e.g., gantry cranes, terminal tractors, reach-stackers). Exceptions are categorized separately and include electric forklifts and ship-to-shore cranes.*

Microgrid Technology Distributed Energy Resource Electrification End Use

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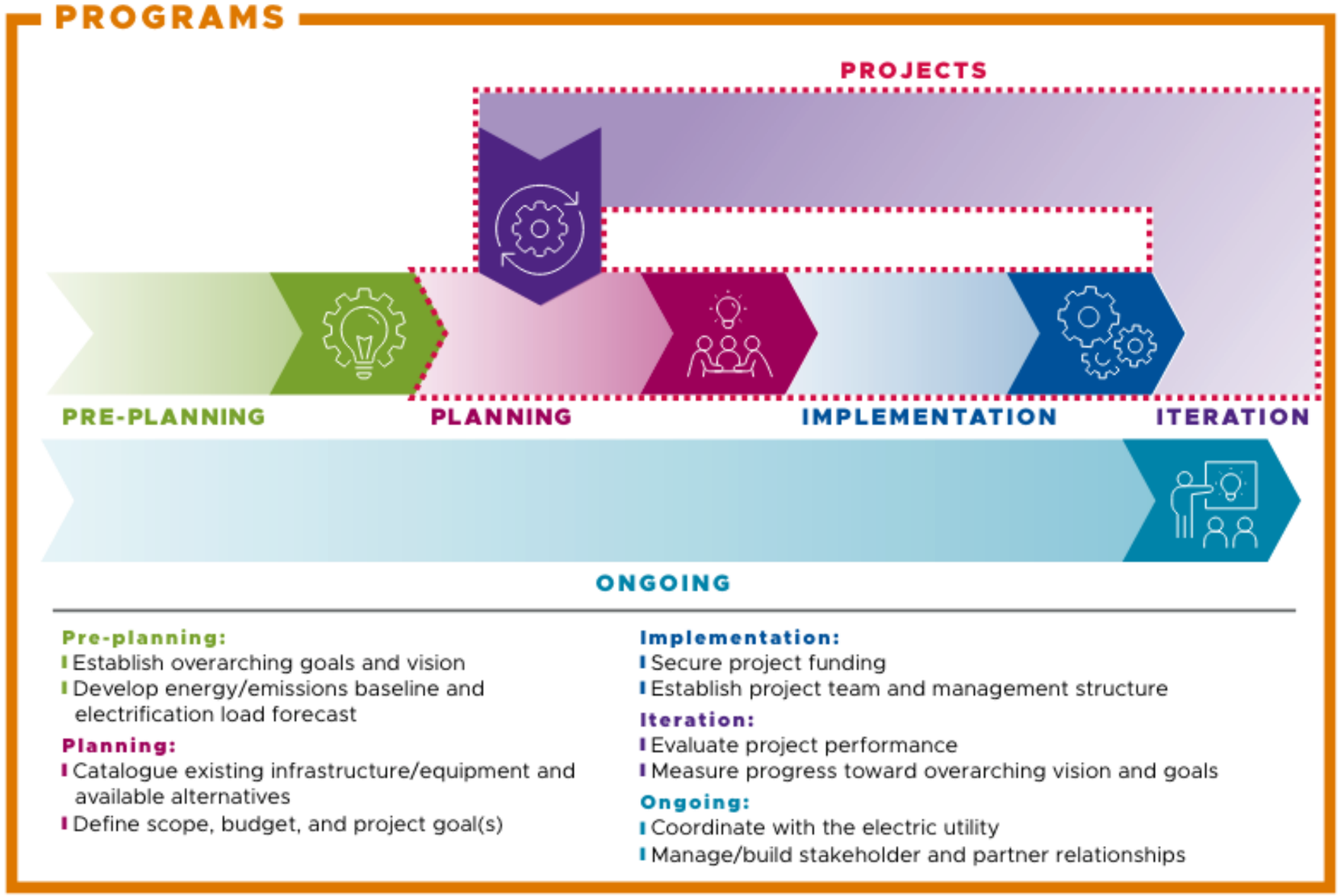
Planning for Port Electrification



Utility Coordination Opportunities

Organization

- Establish ongoing communications schedule, potentially outlined in a joint agreement
- Develop collaborative relationships across organizations, including at the leadership and staff level

Planning

- Conduct electric infrastructure assessment
- Coordinate on planning efforts including establishing a load baseline and forecast

Collaboration

- Engage utilities in regional coordination efforts
- Co-develop proposals for grants and other funding opportunities
- Explore solutions for any regulatory hurdles, including applying for exceptions from the public utilities commission

Understanding

- Identify potential rate structures supporting port electrification
- Learn about available utility programs and incentives

Regional Coordination

- It is often most effective if ports move in unison on certain activities.
- This can avoid any one port placing themselves at a competitive disadvantage.
- It can also leverage combined influence of multiple ports.
- Regional stakeholders could consider coordinating on:
  - Emissions reduction targets
  - Industry engagement and partnerships
  - Advocating for desired policies and funding
  - Infrastructure and alternative fuels planning
- Example: Northwest Ports Clean Air Strategy

Scope of the Northwest Ports Clean Air Strategy

IMAGE SOURCE: https://www.nwseaportalliance.com/environment/clean-air/northwest-ports-clean-air-strategy

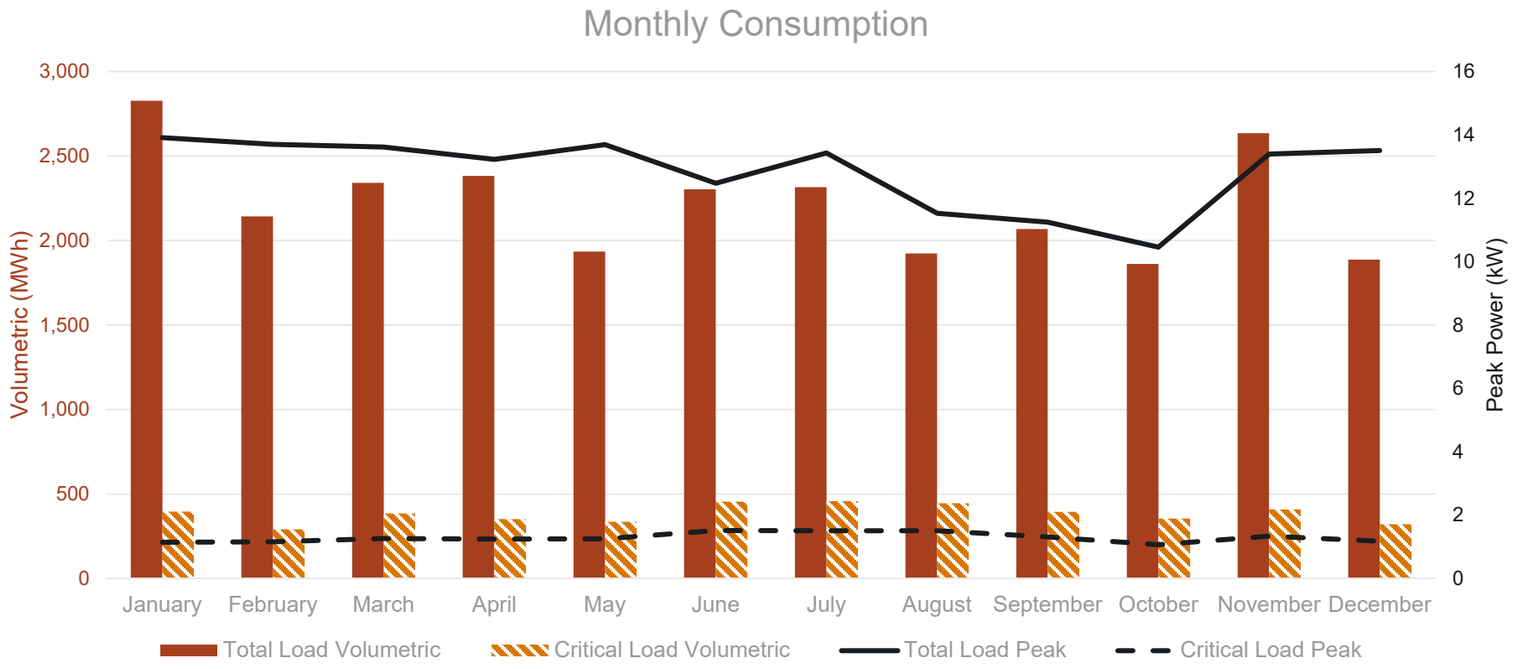
Technoeconomic Analysis

- **Technoeconomic Analysis (TEA)** enables stakeholders to assess the costs and benefits associated a potential technology transition.
- The Handbook included multiple TEA examples based on real-world scenarios at the Port of Alaska and Port of Seattle (forthcoming).
- Can be done for an individual piece of equipment or a system.
- Typical goals include improved economic efficiency, environmental benefit, and resiliency.
- Potential costs and benefits in a TEA related to port electrification may include:

Potential Costs	Potential Benefits
Capital costs	Electricity bill management
Maintenance and operation costs	Demand charge reduction
Electricity costs	Critical infrastructure upgrade deferral
Switching costs (e.g., permitting, workforce training)	Emissions reductions
Decommissioning of old equipment	Resiliency enhancement
Other socioeconomic impacts	Other socioeconomic impacts

Load & Generation Profile Workbook

Input				
		Unit	Total	Critical
Cargo Handling Equipment	STS Cranes	Single-Berth Terminal	2	1
		Two-Berth Terminal	1	0
		Three-Berth Terminal	0	0
	Forklift	One vehicle	8	0
	Generic Rolling CHE	One vehicle	3	0
Exterior Lighting		Acre	600	300
Switch Locomotive Charging		One Locomotive	2	1
EV Charging	LDV	4-Bay Charging Station		
	MDV/HDV	4-Bay Charging Station	2	1
Shorepower	Container	Single-Berth Terminal	2	
		Two-Berth Terminal		
		Three-Berth Terminal		
	Cruise	Single-berth Terminal	1	
Reefer Units	20-foot Refrigerated	One Container	50	50
	40-foot Refrigerated	One Container	30	30
	20-foot Freezer	One Container	45	45
	40-foot Freezer	One Container	20	20
Buildings	LargeOffice	One building		
	MediumOffice	One building	2	
	SmallOffice	One building	3	2
	LargeHotel	One building		
	SmallHotel	One building		
	Warehouse	One building	5	2
	FullServiceRestaurant	One building		
	QuickServiceRestaurant	One building		
Other 1				
Other 2				



Example inputs to the Maritime Port Load and Generation Profile Workbook → Draft output of estimated monthly energy consumption.

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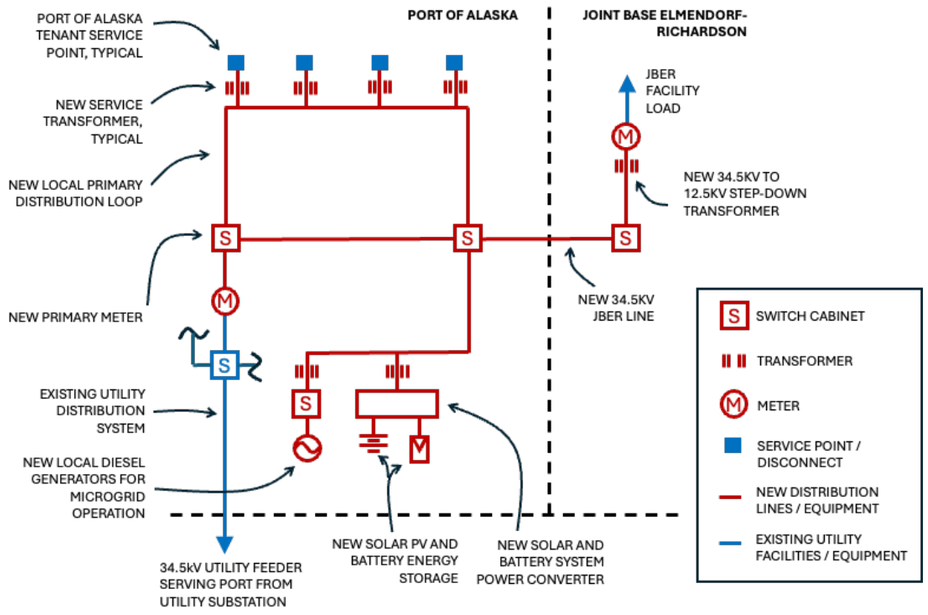
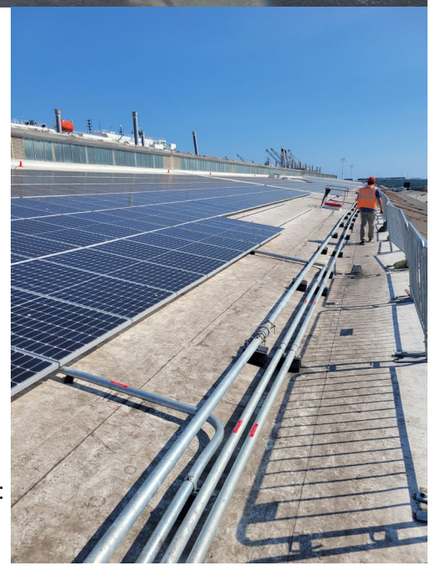
Don Young Port of Alaska Meter Study and Microgrid Options Evaluation

- Examined microgrid options for resilient operations of the port and nearby Joint Base Elmendorf-Richardson
- Different topologies and technologies via techno-economic evaluation
- "Lessons Learned"
  - Multi-year process with different stages blending together
  - Shifting scope of project with time
    - ✓ Initially electrical infrastructure
    - ✓ Recent considerations of hydrogen and e-fuels
  - Evaluation of deployments against environmental hazards (tsunami, earthquake, etc.)



Port of Long Beach Port Microgrid Deployment

- Deploy microgrid to provide backup power to Joint Command and Control Center
- Integrated some “common” technologies
  - BESS –mobile platform
  - Rooftop PV
  - Diesel generator
- “Lessons Learned”
  - Crossing fencelines
    - ✓ Regulatory exemptions
    - ✓ Operational considerations
  - AHJ additional requirements
    - ✓ Rooftop PV – building/site challenges
    - ✓ BESS proximity – fire rating changes
    - ✓ Control – Vendor cloud-based interfaces were prohibited



Photos credit: Port of Long Beach

Thank you

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Handbook Website

https://www.pnnl.gov/projects/port-electrification-handbook