Pacific Northwest
NATIONAL LABORATORY

EXECUTIVE SUMMARY – PORT ELECTRIFICATION HANDBOOK

A Reference to Aid U.S. Port Energy Transitions

May 2024

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Prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830

PNNL-SA-198636

U.S. DEPARTMENT OF ENERGY

Port electrification can take many forms, such as electrifying cargo handling equipment or deploying a microgrid to power critical port infrastructure. To help evaluate the growing challenge of increased electrification and its impacts on the system, Pacific Northwest National Laboratory developed this Port Electrification Handbook with support from the U.S. Department of Energy, Office of Electricity's Microgrids R&D [research and development] program. The goals of this handbook are the following:

- Help port operators and planners evaluate different electrification technologies
- Explain how these technologies could aid and impact ports and surrounding communities
- Provide step-by-step considerations for port electrification.

Overview of Port Electrification: In most cases, port infrastructure is traditionally powered by fossil fuels (e.g., diesel, natural gas, heavy fuel oil), and the term "electrification" generally refers to powering this infrastructure and equipment by electricity, instead. Electricity can be provided via a battery, hydrogen fuel cell, or through direct connection to an electrical source such as the utility grid or solar photovoltaic panels.

Port electrification can generate a variety of benefits for ports and near-port communities and help address climate change. Those who live and work near ports are impacted inequitably by diesel exhaust, particulate matter, and nitrous oxides that are linked to respiratory and cardiovascular diseases, lung cancer, and premature mortality.[1] Using clean electricity to power port operations reduces these harmful impacts of port activity and advances environmental justice.

Figure ES.1 describes other potential benefits and challenges of port electrification. Though all ports can benefit from electrification to some degree, the approach will vary port by port based on factors that include a port's location, electricity cost, electricity generation, operations, and operational structure. For example, the environmental benefit of electrification will be more pronounced for ports powered by renewable energy sources compared to ports that rely on utility grids primarily powered by coal or natural gas.

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

Figure ES.1 | Potential benefits and challenges of port electrification.

[1] Bailey, D., and G. Solomon. 2004. "Pollution Prevention at Ports: Clearing the Air." Environmental Impact Assessment Review 24 (7–8): 749–774. *https://doi.org/10.1016/j.eiar.2004.06.005*.

The electrification technologies discussed here in the Port Electrification Handbook—including distributed energy resources (DERs), microgrids, and electrified end uses—vary in technology readiness and availability. Similarly, ports also vary in risk tolerance and their associated interest in investing in early-stage technologies. Grants and other financial incentives could help ports and stakeholders overcome some investment risk. Nonetheless, it is valuable to understand technology readiness and availability when planning potential electrification efforts, which is estimated in **Figure ES.2**.

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 EVs/Charging
	Medium- & Heavy-Duty EVs/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.*
*** On-Port Fuel Production refers to using electricity, potentially generated on-port also, to produce clean alternative fuels such as hydrogen, methanol, or ammonia*

● Microgrid Technology ● Distributed Energy Resource ● Electrification End Use

Figure ES.2 | Electrification technologies map depicting technology availability for DERs, electrification end uses, and microgrid technologies.

Port Microgrids: With the electrification of maritime ports, the potential (and need) to form microgrids at a port becomes significant.

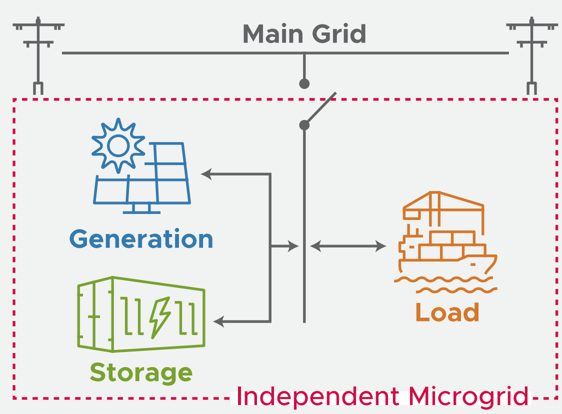
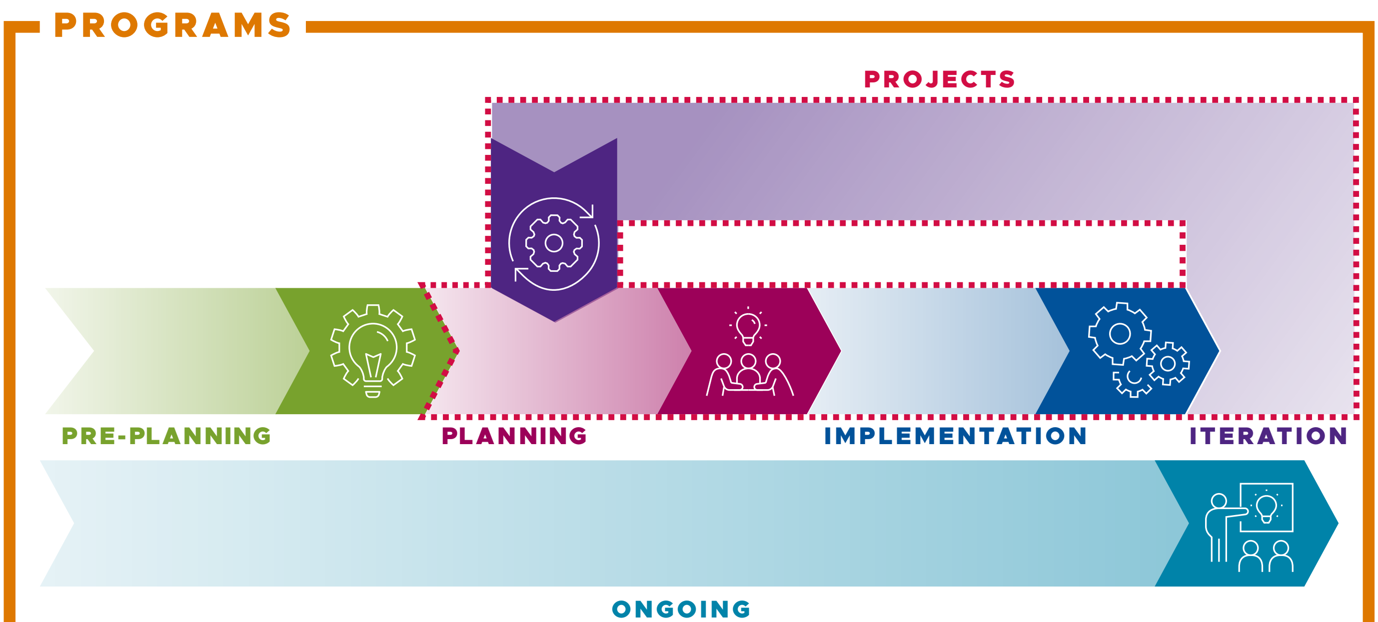


Figure ES.3 | Example of an independent port microgrid.

Intermittent disruptions from the bulk power system can interrupt the power supply to the electrified port, resulting in an impact to port operations. Microgrids not only enable a backup source of power for critical facilities, but they can also be used to keep operations running during shorter outages or enable a limited set for disaster recovery. In certain power markets and infrastructure scenarios, microgrids may also be a way to either save feeder upgrade or increased demand charges, or possibly even sell services back to the bulk power system. The Port Electrification Handbook describes different types of microgrids, including independent microgrids (**see Figure ES.3**) and more complex community and networked microgrid designs. It also discusses key planning considerations for microgrids and how to assess their potential value through technoeconomic analysis.

Planning for Port Electrification: The Port Electrification Handbook provides high-level guidance on electrification program planning and implementation, to help inform port, tenant, and other stakeholder efforts. It will not capture every task for every port because each is incredibly unique. Instead, the guidance is intended to provide a template for ports and stakeholders to build on in their respective efforts, a road map of planning phases and tasks to consider within each phase, and potential structure to support the sometimes-ambiguous process of port electrification.

The Port Electrification Program Management Framework, outlined in **Figure ES.4**, summarizes the phases of port electrification and example tasks within each phase. It aims to align with the incremental investment process and ongoing iteration that is often undertaken to achieve overarching electrification and decarbonization goals. It includes four defined phases—Pre-planning, Planning, Implementation, and Iteration—and lists ongoing tasks that are important at all phases. Though outlined sequentially and in distinct categories, in practice, the boundaries between the phases blur, and it is highly likely that multiple phases will occur at the same time.



Pre-planning:
- Establish overarching goals and vision
- Develop energy/emissions baseline and electrification load forecast

Planning:
- Catalogue existing infrastructure/equipment and available alternatives
- Define scope, budget, and project goal(s)

Implementation:
- Secure project funding
- Establish project team and management structure

Iteration:
- Evaluate project performance
- Measure progress toward overarching vision and goals

Ongoing:
- Coordinate with the electric utility
- Manage/build stakeholder and partner relationships

Figure ES.4 | Port Electrification Program Management Framework and example tasks in each phase.

Utility Coordination

Port electrification must be accomplished hand-in-hand with the electric utility.

Ports can design and plan for various electrified end uses, but projects will only move forward if the required electrical service can be made available. Coordinating closely with the electric utility can also offer increased efficiencies, potential cost savings, and partnership and information sharing opportunities.

A Regional Approach to Port Electrification

It is often most effective if regional groups of ports move in unison on certain activities. This can enable a systems approach to implementing new technologies and help ports avoid placing themselves at a competitive disadvantage (e.g., by requiring electrification when their neighbor ports do not). A regional approach also helps increase participating ports' influence on regional customers and leverage to advance policies supporting port electrification, for example, in state and federal legislature.

The maritime sector is experiencing an unprecedented demand from international, national, and sometimes regional forces to transition toward cleaner energy sources, including electricity. This demand is coupled with an influx of funding, largely from federal sources, that will support port energy transition activities and infrastructure buildout. Though the road ahead is largely unpaved, there is an increasing library of lessons learned from the implementation efforts of industry leaders and resources, such as this handbook, that help guide port efforts. Port electrification, when planned carefully with relevant stakeholders, can facilitate port energy transitions and strengthen the resiliency of the nation's critical infrastructure while advancing environmental justice.

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PNNL-SA-198636 | Updated May 2024

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