Hourly Load Profile Dataset for Electric Port Cargo Handling Equipment in the United States

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NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated under Contract No. DE-AC36-08GO28308

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Technical Report
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Suggested Citation
Polemis, Katerina, Andrew Kotz, Kara Podkaminer, and Brennan Borlaug. 2025. *Hourly Load Profile Dataset for Electric Port Cargo Handling Equipment in the United States*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400-92141. https://www.nrel.gov/docs/fy25osti/92141.

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NOTICE

This work was authored in part by the National Renewable Energy Laboratory for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Vehicle Technologies Office. The views expressed herein do not necessarily represent the views of the DOE or the U.S. Government.

Cover photos (clockwise from left): Josh Bauer, NREL 61725; Visualization from the NREL Insight Center; Getty-181828180; Agata Bogucka, NREL 91683; Dennis Schroeder, NREL 51331; Werner Slocum, NREL 67842.

Acknowledgments

The authors gratefully acknowledge Catherine Ledna (National Renewable Energy Laboratory [NREL]) and Marcus Alexander (Electric Power Research Institute [EPRI]) for their insightful reviews and valuable recommendations. Special thanks are extended to Jamie Dunkley, Britta Gross, and Jennifer Kwong from EPRI for their guidance and Mike Weismiller (U.S. Department of Energy) for his continued support. Michael Deneen (NREL) provided copyediting assistance and Cameron Nelson (NREL) provided graphics assistance.

List of Acronyms

CHE	cargo handling equipment
eCHE	electric cargo handling equipment
EVSE	electric vehicle supply equipment
STS	ship to shore
TEU	twenty-foot equivalent unit

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1 Introduction

U.S. maritime ports are integral to both the domestic and global economy, supporting 21.8 million jobs and contributing $2.9 trillion to the U.S. gross domestic product (American Association of Port Authorities 2024). Maritime shipping accounts for approximately 90% of global trade by volume (International Chamber of Shipping 2025), emphasizing the importance of efficient and reliable ports in maintaining global supply chains. Furthermore, ports are uniquely positioned to become future clean energy hubs, acting as critical intersections of multiple energy systems—such as electricity, hydrogen, ammonia, and methanol—and diverse freight transportation modes, including on-road tractors, rail, and maritime vessels.

Historically, ports have relied on fossil fuels, particularly diesel, as their primary energy source. At the Port of Los Angeles, one of the busiest ports in the United States, cargo handling equipment (CHE)–including ship-to-shore (STS) cranes, yard tractors, and top handlers for moving freight to and from ships and throughout the port–account for approximately 15% of the port's CO_2 emissions (Vairamohan, 2023). Transitioning to electric cargo handling equipment (eCHE) offers a promising solution for eliminating tailpipe emissions, reducing harmful airborne particulates, lowering noise pollution, and supporting decarbonization.

This study develops an initial estimation of hourly electricity demand for eCHE at the top 25 container ports (by tonnage) in the United States. These datasets, accessible at data.nrel.gov/submissions/281, provide valuable insights into the electricity demand patterns and potential grid impacts of widespread eCHE adoption, forming a foundation for future refinement based on stakeholder feedback.

2 Methods

To develop electricity demand profiles for eCHE, a representative operating profile is first developed for a "reference" U.S. container port. This profile incorporates detailed CHE inventories, operating hours, and the resulting fuel use and/or electricity consumption of this equipment. The reference port is modeled, in part, after the Port of Honolulu in Hawaii, which ranks near the middle of the top 25 U.S. container ports (Figure 1) by annual container throughput (Bureau of Transportation Statistics, n.d.). This positioning is assumed to make the Port of Honolulu a reasonable representation of a typical large container port in the United States.

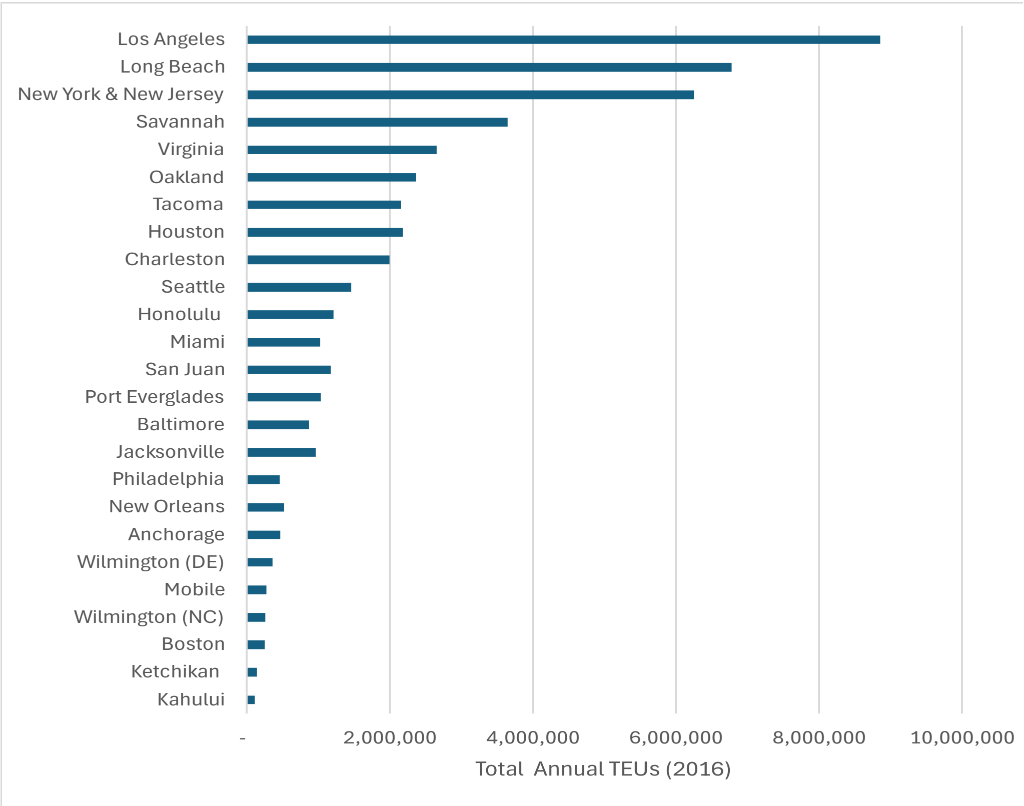

Figure 1. Top 25 U.S. container ports by total tonnage (2016)

A twenty-foot-equivalent unit (TEU) is a unit of measurement used in the shipping industry to denote the capacity of a standard intermodal container, which has a length of twenty feet. The energy consumed per container moved (kilowatt-hours per TEU)—from ship to shore and through the port—is estimated from real-world operating data. This estimate is scaled based on annual TEU throughput and extrapolated to generate individual electricity demand profiles for the top 25 U.S. container ports. Additionally, eCHE adoption rates are analyzed to develop forecasts from 2023 to 2035, projecting increased adoption and a corresponding growth in electricity demand over time.

2.1 Determining a Reference U.S. Port Operation

Operational data from the National Renewable Energy Laboratory's Fleet Research, Energy Data, and Insights (FleetREDI) commercial vehicle database and analysis platform, combined with data from the Port of Honolulu, are used to inform assumptions for a representative U.S. port operation. The FleetREDI dataset consists of 1-Hz telematics data from conventional CHE, including second-by-second diesel fuel consumption (summarized in Figure 2). To estimate the equivalent electricity consumption for eCHE, the energy content of diesel fuel is converted to an equivalent electricity demand, accounting for the approximately threefold efficiency advantage of electric motors over diesel engines.

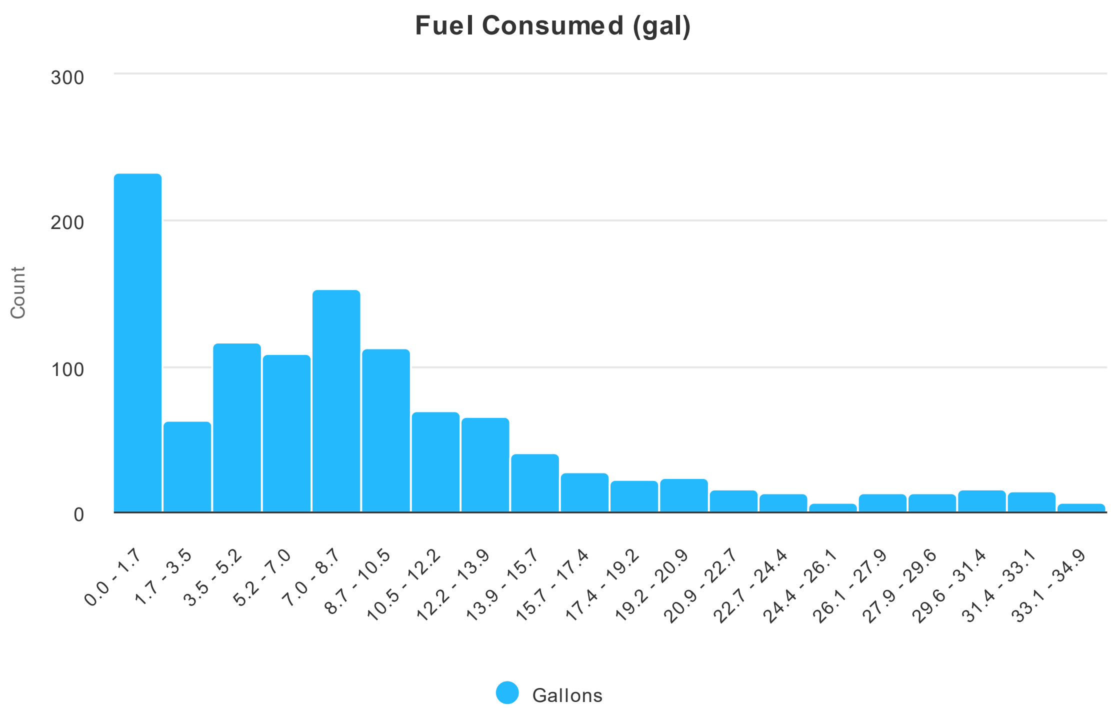

Figure 2. Real-world average daily diesel fuel consumption for CHE (FleetREDI, n.d.)

In contrast, data from the Port of Honolulu are more aggregated, providing only hourly energy consumption values for the various CHE types. Electric vehicle supply equipment (EVSE) power levels are also sourced from the Port of Honolulu, based on the specifications of eCHE models available today.

Table 1 categorizes the different eCHE considered in this analysis by power source: battery-powered and grid-connected. All equipment is assumed to operate for the full duration of a shift cycle, with battery-powered eCHE only charging during off-shift hours. In contrast, STS cranes are the only grid-connected equipment modeled and are assumed to draw power concurrent with their operation.

Table 1. Reference Port eCHE Electricity Consumption

Vehicle Type	Min. Hourly Consumption (kWh)	Max. Hourly Consumption (kWh)	EVSE (kW)	Power Source
Pickup trucks	6.3		24	Battery-powered
Tour vans	0.8		24	
Personnel vehicles	14.2		24	
Yard tractors	126.6	127.1	150	
5-ton forklifts	8.9	10.8	150	
15-ton forklifts	26.6	32.3	150	
Top handlers	308.8	334.5	180	
STS cranes	392.3	726.2	-	Grid-connected

A single operational profile is developed for the reference port. For this study, a two-shift operation is assumed to reflect typical port activity. The Port of Tacoma operates on a two-shift schedule and was therefore selected for the reference port operating profile (Table 2).

Table 2. Reference Container Port Operating Profile

Description	Hours
Day shift ***(7 a.m. to 5 p.m.)***	10
Night shift ***(6 p.m. to 2 a.m.)***	8
Total daily	18
Total annual ***(52 weeks per year)***	5,616

The operational profiles are used to estimate the daily electricity consumption of eCHE. The annual TEU throughput for the Port of Honolulu is then applied to estimate the total electricity consumed to move a loaded container from the vessel to the dock and through the port. The analysis estimates that 14.6 to 20.6 kWh of electricity is consumed per loaded TEU. A detailed breakdown of this demand by loading/unloading stage and eCHE type is presented in Figure 3.

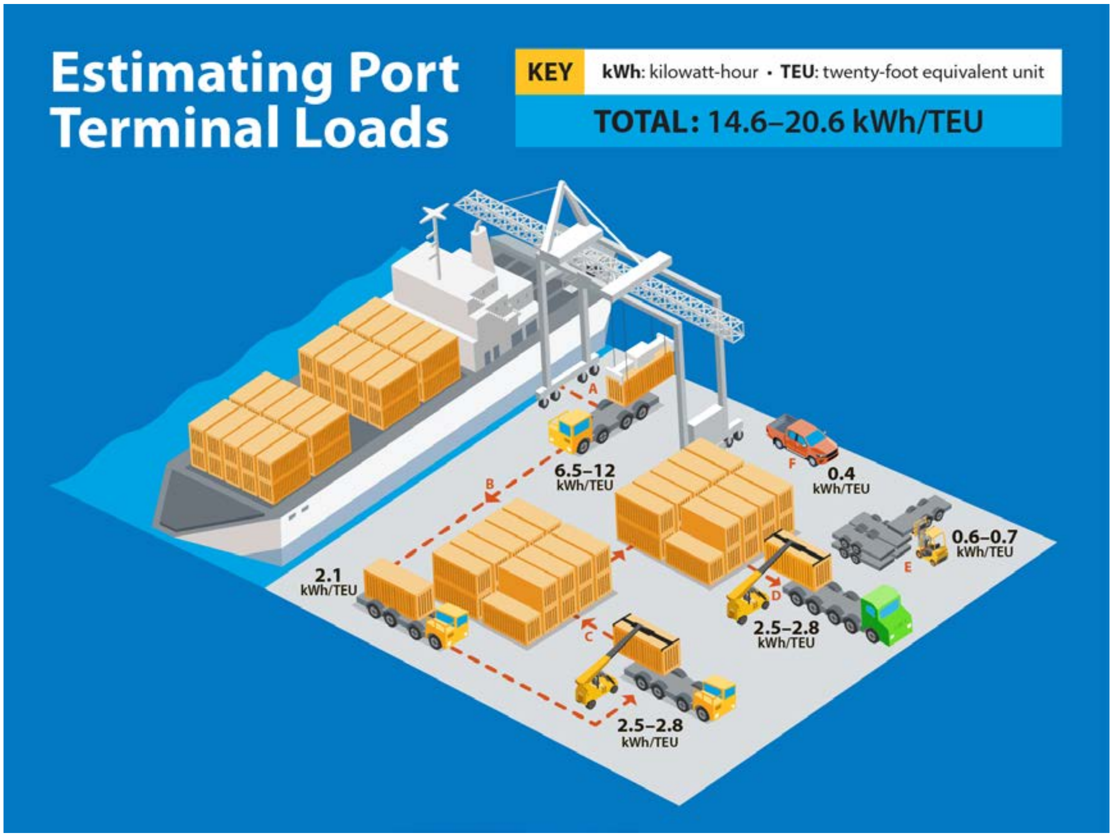

Figure 3. Modeled eCHE electricity consumed to move a container through the port

It is important to note that the specific layout and footprint of a port can significantly impact the energy consumption of eCHE. However, this factor was determined to be outside the scope of this analysis and is therefore not considered.

2.2 Extrapolating TEU-Based Electricity Demand to the Top 25 U.S. Ports

The 14.6–20.6 kWh of electricity required to move a loaded TEU off a ship and through the port with eCHE is adjusted to account for the approximately 12% of electricity that is lost during charging due to battery conditioning and transmission inefficiencies (Voelcker 2021). The resulting electricity demand is then extrapolated to the top 25 U.S. container ports (Bureau of Transportation Statistics 2024) and scaled according to each port's annual TEU throughput. This extrapolation produces an intermediate dataset that estimates the total annual electricity demand for eCHE at each port, assuming 100% eCHE adoption. A snapshot of this dataset, highlighting the top three ports by annual TEU throughput, is presented in Table 3. The final load profiles are then adjusted from the 100% adoption scenario to reflect varying adoption rates.

Table 3. Estimated Annual Electricity Demand for 100% eCHE Fleet (Top 3 Container Ports)

Port	Annual Electricity Demand (MWh)
New York & New Jersey	93,636
Long Beach	102,060
Los Angeles	130,891

CHE inventories are assumed to scale in proportion to each port's TEU throughput, following a linear relationship between throughput and CHE stock. This scaling method is validated using publicly available data on STS cranes at the Ports of Los Angeles and Long Beach. Table 4 displays the scaled inventories for the top three container ports in the United States.

Table 4. CHE Inventories for Top 3 U.S. Container Ports

Port	Annual TEU Throughput	Pickup Trucks	Tour Vans	Personnel Vehicles	Yard Tractors	5-ton Forklifts	15-ton Forklifts	Top Handlers	STS Cranes
New York & New Jersey	6.2 million	92	11	104	173	11	11	57	57
Long Beach	6.8 million	100	12	112	188	12	12	62	62
Los Angeles	8.9 million	131	16	147	246	16	16	82	82

From these scaled equipment inventories, an hourly eCHE electricity demand profile is estimated for each port. This profile captures the combined electricity demand from battery-powered eCHE charging and STS crane operations. Battery-powered eCHE is assumed to begin charging immediately during off-shift hours at its EVSE-rated power level until fully charged, while STS cranes consume electricity continuously at the rates specified in Table 1.

2.3 eCHE Adoption Rates at U.S. Ports

A literature review was conducted to evaluate current eCHE adoption rates at U.S. ports. Pilot programs include 12 electric yard tractors at the Port of Long Beach (Port of Long Beach 2024) and electric top handlers at the Port of Los Angeles (Port of Los Angeles 2024). Additionally, the Port of Long Beach developed a blueprint for zero-emission operations (Port of Long Beach 2025b) outlining eCHE adoption targets through 2030 (Table 5).

Table 5. Port of Long Beach eCHE Adoption Targets

Year	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
eCHE Adoption	0%	0%	4%	9%	14%	20%	27%	35%	45%	57%	70%	84%	100%
Total eCHE	9	9	33	41	41	50	57	62	82	98	107	115	132

The eCHE adoption rates modeled in this analysis are based on the trajectories outlined in Table 5, but adjusted to achieve 100% eCHE penetration by 2040, rather than 2030, reflecting a more conservative transition compared to the Port of Long Beach. Adoption rates are assumed to remain consistent across CHE types, in line with the assumptions in the blueprint, particularly for STS cranes and yard tractors. The eCHE adoption trajectory, applied to all ports in this analysis, is shown in Table 6.

Table 6. Modeled Cumulative EV Adoption Rate for All Ports in this Study

Year	eCHE %
2023	8%
2024	10%
2025	12%
2026	15%
2027	18%
2028	22%
2029	26%
2030	31%
2031	36%
2032	42%
2033	48%
2034	54%
2035	61%
2036	68%
2037	76%
2038	84%
2039	91%
2040	100%

3 Port eCHE Electricity Demand Dataset

The final dataset includes hourly electricity demand profiles for eCHE at the top 25 U.S. container ports (Table 7). Annual datasets are provided for the years 2023 through 2035, along with a “100% eCHE” scenario.

Table 7. Port eCHE Electricity Demand Dataset Description

Feature	Details
Vehicle segment(s)	eCHE
Years	2023–2035 and 100% eCHE
Spatial resolution	Port level, top 25 U.S. container ports
Temporal resolution	Hourly

3.1 Dataset Assumptions

All ports in the dataset are assumed to have a consistent operational profile with a two-shift schedule: a morning shift (7 a.m. to 5 p.m.) and a night shift (6 p.m. to 2 a.m.), as outlined in Table 2. Annual eCHE penetration rates, equipment types, and equipment ratios are also assumed to be consistent across all ports, aligning with the reference port.

The following assumptions are made when generating the hourly demand profiles:

- There is a 1:1 ratio between eCHE and EVSE.
- All battery-powered eCHE begins charging immediately at the start of the off-shift period.
- All EVSE operates at its rated power capacity until the eCHE batteries are fully charged.

In practice, peak power demand could be mitigated through managed charging strategies, and EVSE would not maintain its maximum power output throughout the entire charging period.

3.2 Dataset Visualization

The estimated hourly load profiles for the top three U.S. container ports, assuming a 100% eCHE fleet, are presented in Figure 4. Peak power demand occurs during off-shift hours when battery-powered eCHE are assumed to charge. While this peak could be mitigated through managed charging, such strategies are not modeled in this dataset. During on-shift hours, only grid-connected STS cranes consume electricity.

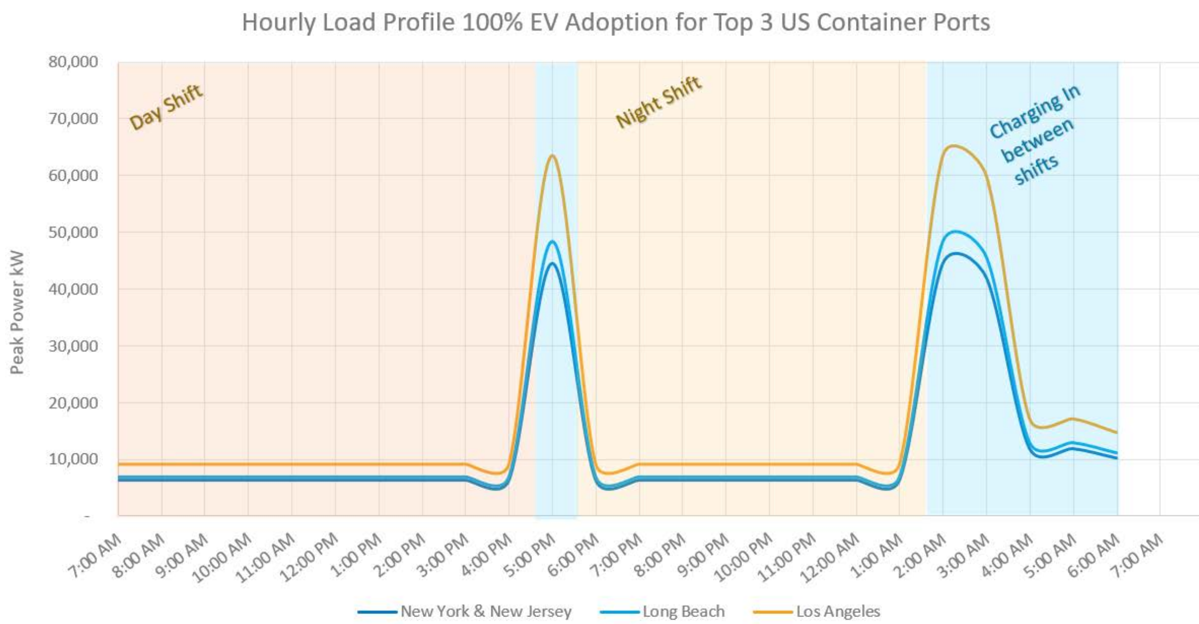

Figure 4. Hourly eCHE load profiles for the top three U.S. container ports (New York and New Jersey, Long Beach, and Los Angeles) assuming 100% eCHE adoption

4 Dataset Guidelines and Limitations

This dataset, available at data.nrel.gov/submissions/281, provides a scalable approach for estimating future electricity demand from eCHE at U.S. container ports. As an initial estimation, it aims to assist ports, utilities, and energy planning stakeholders in preparing electricity supply infrastructure to accommodate the anticipated demand from increased eCHE adoption. By addressing a notable gap in the current data landscape, it provides a foundation for modeling the impacts of port electrification on electricity systems.

However, several limitations and caveats should be acknowledged when using these data. Port-specific operational characteristics—including equipment inventories, operational schedules, annual energy usage, and TEU throughput—are key drivers of eCHE electricity demand. These results could be improved in the future by incorporating more detailed, port-specific data to represent the anticipated variability in operations. Additionally, bottom-up charging simulations would better capture the variability in charging load compared to the approach described here.

This dataset should be considered a methodological foundation rather than a definitive prediction. By integrating port-specific CHE inventories, operational data, environmental factors, and electrification goals, stakeholders can refine and customize this approach to generate tailored load profiles for individual ports or terminals. These enhancements will support more precise energy demand forecasting, facilitating proactive infrastructure planning and sustainable port electrification.

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