Exhibit C

Port of Cleveland Electrification and Net Zero Emissions Master Plan

Electrification and Net Zero Emissions Master Plan

Revision No: 1

Executive Summary

The Cleveland-Cuyahoga County Port Authority (Port Authority) is taking a notable step to eliminate emissions from the Port of Cleveland (Port) as well as the surrounding communities. The approach to view emissions in their entirety, including grid electrical power and marine vessel–generated emissions, is a key differentiator that will ultimately benefit Cleveland over the coming decades.

The combination of a completely battery electric cargo handling equipment fleet, hybrid tethered mobile harbor cranes, and cargo and cruise cold ironing, paired with innovative solar photovoltaic systems, is the recommended path for the Port Authority to realize its ambitions of a net-zero emission facility and operation. Further detailed energy modeling and planning should be undertaken to quantify the exact impact as technologies and policies evolve, but this master plan provides the necessary direction and foundation in a constantly evolving industry.

Although battery electric equipment and vehicles was identified as the ideal technology for the Port Authority, primarily due to availability, cost, and operational feasibility, it should also be noted that the Port Authority should concurrently stay abreast with hydrogen fuel cell technologies. The Great Lakes and Ohio could potentially play a large role in a future hydrogen and hydrogen feedstock economy, which could dramatically affect hydrogen availability and pricing long term, improving the viability of this technology. Cold-weather performance of fuel cell versus battery electric could also have an impact, with vehicle pilots being the best way to confirm vehicle manufacturer claims, test differing battery types and architectures, and gather crucial data to inform planning and procurements in the future.

Warehouse A has been reimagined as a central hub, not just for the Port's cargo handling operations, but also as an electrification hub capable of supplying the needed power for future zero-emission (ZE) projects, specifically the expansion spokes of charging and cold ironing. Central to the Warehouse A electrification hub's development is adequate planning with Cleveland Public Power (CPP) to develop a new 12-kilovolt (kV)-capable feed and incoming feed with allocated power capacity of at least 2 megawatts. This amount of additional capacity is expected to be all that is required to serve the future ZE fleet and cold ironing for cargo vessels, and should be protected for the Port Authority's future development. Continuous CPP engagement should continue to ensure alignment with future lakefront development planning and City of Cleveland initiatives.

An important next step for the development of a battery electric charging hub at Warehouse A is to decide upon exact models of electric vehicle (EV) chargers to be used to finalize the electrical infrastructure upgrades and the number of EV chargers. Once charging and refueling infrastructure is in place, the operation and maintenance phase becomes vital for the success of the ZE transition. It is recommended that the Port Authority create a ZE fleet operation and maintenance plan to outline the procedures, maintenance protocol, and responsibilities for the new equipment, vehicles, and supporting charging infrastructure. Workforce development and training is also imperative to prepare the Port for a successful transition and long-term stability of ZE fleet practices.

In addition to the Warehouse A electrification hub, a critical element of electrification and ZE is the development of a future Port Cruise Terminal with a dedicated power generation facility capable of future ZE operation, or a separate CPP 12-kV power connection, to power large cruise ships, such as the *Viking Polaris*, while at berth. The *Viking Polaris* and other Great Lakes cruise vessels are cold ironing capable today, providing an opportunity for the Port Authority to decrease tangible emissions in the near term. Substantial development work and multi-agency alignment is required though in order to develop this project. It is recommended that the Port Authority and the City of Cleveland develop a cruise terminal plan that can bridge the gap between the current North Coast Master Plan, the Port Authority's General Cargo Terminal development plan, and this electrification and net zero emissions master plan. The Cruise Terminal presents a substantial economic value and opportunity to the City of Cleveland, while also developing the first Great Lakes cruise terminal with cold ironing capabilities.

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Acronyms and Abbreviations

CMS	cable management system
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CPP	Cleveland Public Power
DC	direct current
DPM	diesel particulate matter
DWT	deadweight tonnage
EAC	Energy Adjustment Charge
EPA	U.S. Environmental Protection Agency
EV	electric vehicle
EVSE	electric vehicle supply equipment
GCT	General Cargo Terminal
GHG	greenhouse gas
GWh	gigawatt-hour(s)
hp	horsepower
ICE	internal combustion engine
IRA	Inflation Reduction Act
ITC	Investment Tax Credit
kV	kilovolt(s)
kVA	kilovolt-ampere(s)
kW	kilowatt(s)
kWh	kilowatt-hour(s)
MW	megawatt(s)
MWDC	megawatt(s) direct current
MWh	megawatt-hour(s)
NO_x	nitrogen oxides
OEM	original equipment manufacturer
Port	Port of Cleveland
Port Authority	Cleveland-Cuyahoga County Port Authority

PPA	power purchase agreement
PTC	Production Tax Credit
PV	photovoltaic
RFCW	Reliability First Corporation West
V	volt(s)
ZE	zero emission
ZEV	zero-emission vehicle

1. Introduction

1.1 Purpose of the Electrification and Net Zero Emissions Master Plan

The Port of Cleveland (Port) is a vital industrial and commercial hub, serving the needs of people and businesses in Northeast Ohio and beyond. The Cleveland-Cuyahoga County Port Authority (Port of Cleveland) distinguishes itself as a leader in environmental stewardship and innovation in sustainability. As part of this project, the Port Authority seeks to develop a comprehensive electrification and net zero emissions master planning document to guide capital facility improvements, vehicle procurements, and cold ironing initiatives with shipping and cruise lines over the next 20 years as the Port expands and grows its cargo and cruise ship operations. This master planning document will outline strategies to transition the entire cargo handling, support vessel, yard tractor, and light-duty vehicle fleet to battery electric or hydrogen, as well as battery electric switching locomotives and ship cold ironing.

Currently, a vehicle fleet comprised of cargo handling equipment, yard tractors, rail locomotives, mobile harbor cranes, and light-duty vehicles operates at the Port of Cleveland. The contracted terminal operator, Logistec, owns and operates the majority of the cargo handling equipment used onsite. The Port of Cleveland itself owns the mobile harbor cranes and container reach stacker equipment, which are operated by Logistec in normal daily cargo handling operations. The rail locomotive is owned and operated by a second contractor, Omnitrax, which provides railcar switching services for the Port of Cleveland facilities. Annually, it is calculated that the Port's fleet currently consumes 59,664 gallons of off-road diesel and 1,343 gallons of gasoline. These annual fuel consumptions numbers equate to $252,916.00 (for off-road diesel) and $4,986.00 (for gasoline) using average fuel data on August 7, 2023. This plan will give an overview of the requirements to transition all of these vehicles and equipment to zero-emission (ZE) alternatives, ultimately eliminating all tailpipe emissions from the Port Authority's fleet and reducing operating and fueling costs.

Infrastructure is fundamental to supporting vehicle and vessel deployment with ZE technologies and thus marks a critical step toward the Port Authority's energy transition. ZE vehicles and vessels, such as battery electric and hydrogen fuel cell versions, offer many benefits compared with vehicles and vessels run by fossil fuels, such as the elimination of tailpipe emissions, noise and pollution reductions, and lower maintenance costs. Additionally, vessel power generators aboard both cargo and cruise vessels that call to the Port make up the majority of current emissions. This plan also addresses the need to implement cold ironing, also known as shore power, for visiting cargo and cruise vessels.

Ultimately the master plan will define a roadmap to decarbonizing the Port's operations by doing the following:

- Reviewing the existing facilities, infrastructure, and vehicles
- Evaluating available and developing zero-carbon alternatives
- Determining the applicability of zero-carbon alternatives to current operations
- Exploring other opportunities to reduce carbon impact such as renewable energy

1.2 Port Overview

The Port's General Cargo Terminal is composed of separate buildings and warehouses situated around a central roadway, Erieside Avenue. This roadway was previously within public right-of-way but has since been informally incorporated into the Port Authority's property. Warehouse 26 is still owned by the City of Cleveland, but leased to the Port for the Port's use, and the Cleveland Public Power (CPP) electrical distribution infrastructure has remained in the same location and is currently still owned and maintained by CPP within the Port Authority's property. Figure 1-1 and Figure 1-2 illustrate the parcel map and current ownership of the buildings and facilities within the Port of Cleveland.

Figure 1-1. Port of Cleveland Parcel Map

Figure 1-2. Port of Cleveland Parcel Map Key

Key	Owner	Comment
A-H	Port Authority	
I-L	City of Cleveland	
M	City of Cleveland	FirstEnergy Stadium
N	City of Cleveland	Great Lakes Science Center
O	State of Ohio	Rock and Roll Hall of Fame

The Port facility is composed of five distinct operational areas, each dedicated to various cargo and vessel types:

- Break-bulk Cargo Handling Area
  - Dock 24 and Dock 26
  - Warehouse A, Warehouse 24, and Warehouse 26
  - Billet Staging Yard

- Containerized Cargo Handling and Staging Area
  - Dock 22 North and Dock 20 North
- Cruise Ship and Passenger Vessel Area
  - Dock 28A
  - Customs and Border Protection Passenger Intake Building
- Bulk Liquid Transfer Area
  - Dock 20N
- Cement Silo and Storage
  - Dock 20S
- High-capacity Corridor and Special Project Staging (Proposed Future Development)
  - Dock 26
  - Warehouse 26
  - West 3rd Lot Project Staging

Docks 24 and 26 have recently undergone recent civil and paving upgrades as part of a project in 2022 to modernize and rehabilitate dock infrastructure for bulk and project cargo . Included within that project was the installation of electrical conduit duct banks to the four berths of Docks 24 and 26 for future cold ironing. This forward thinking of the Port Authority to include this critical infrastructure in previous infrastructure projects will allow for an easy and cost-efficient transition to cold ironing as vessel lines transition their fleets.

Although different land-based equipment and vehicle types are used within each operational area to support the cargo operations, this plan assumes that all vehicles within the Port Authority's fleet shall be stored, charged, and generally staged in the immediate vicinity of Warehouse A. This approach was selected based on feedback from Port Authority staff, as well as a survey of the facilities and current operations onsite. Warehouse A presented the best candidate to develop centralized incoming high-voltage electrical distribution equipment, as well as place a new maintenance facility. The lowest-cost and most effective operational strategy would be to co-locate the battery electric charging equipment or hydrogen fueling stations with the maintenance staff and near the incoming electrical service from CPP. To establish a baseline of the condition of Warehouse A, a detailed site condition report was developed (Appendix J).

To summarize, Warehouse A is a central point where the majority of cargo operations pass through over a typical day. The building has been in operation since 1975. It is evident that the building needs refurbishment, with substantial structural column and bracing damage within the central coil yard crane bays due to impacts with forklifts and other equipment. Additionally, the Warehouse A office and break areas also require repair and code compliance updates. It is anticipated that through the modernization of Warehouse A, and the establishment of Warehouse A as a central zero-emission vehicle (ZEV) and cold ironing electrification hub, the surrounding building will be modernized to continue to support the Port for decades to come. Figure 1-3 shows Warehouse A within the General Cargo Terminal (GCT) Development Plan.

Figure 1-3. Port of Cleveland General Cargo Terminal Development Plan 2023-2027

1.3 Current Electrical Infrastructure and Capacity

The existing electrical infrastructure consists of a 12-kilovolt (kV) medium-voltage distribution circuit provided by CPP, the electrical utility, to the Port's main gate (Figure 1-4). [redacted]

At the main gate, a 1,500-kilovolt-ampere (kVA) 12-kV to 2.4-kV step-down transformer converts the 12-kV electrical feed to 2.4 kV and distributes it to the various Port warehouses, maintenance and administrative facilities at 2.4 kV. Typical building distribution voltage across the Port is 480 volts (V), with three-phase power, and is provided by pad-mounted transformers with meters adjacent to each individual building. Warehouse A specifically is powered by a 480-V CPP service with the CPP primary metering located on a 500-kVA pad-mounted transformer on the west side, near the offices. During an interview, CPP noted that [redacted] has 2 megawatts (MW) of additional spare capacity. Through continued engagement and interactions with CPP leadership and service planning departments, in addition to the development of a detailed energy analysis and load model for the next 25 years, it is anticipated that this 2 MW of spare capacity can be used for the additional power and energy needs identified within this master plan. Figure 1-4 illustrates the current CPP 2.4-kV and 12-kV medium-voltage distribution architecture currently serving the Port's facilities.

Figure 1-5 and Figure 1-6 display CPP 2022 meter data and usage, which were used to establish the assumed annual building load for the Port for future years.

Figure 1-4. Cleveland Public Power Current Site Infrastructure Illustration

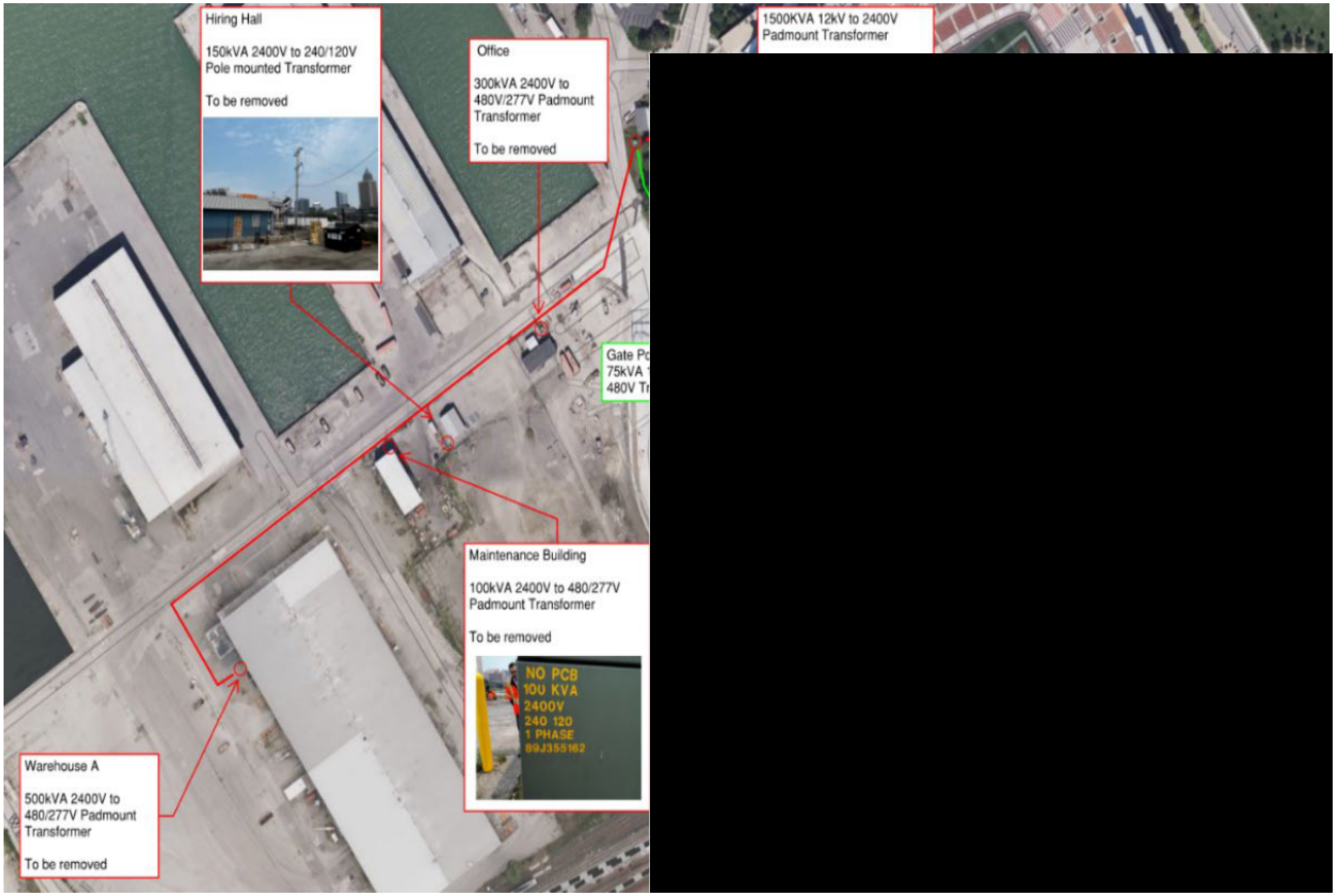


Figure 1-5. Baseline CPP Meter Data and Usage for 2022

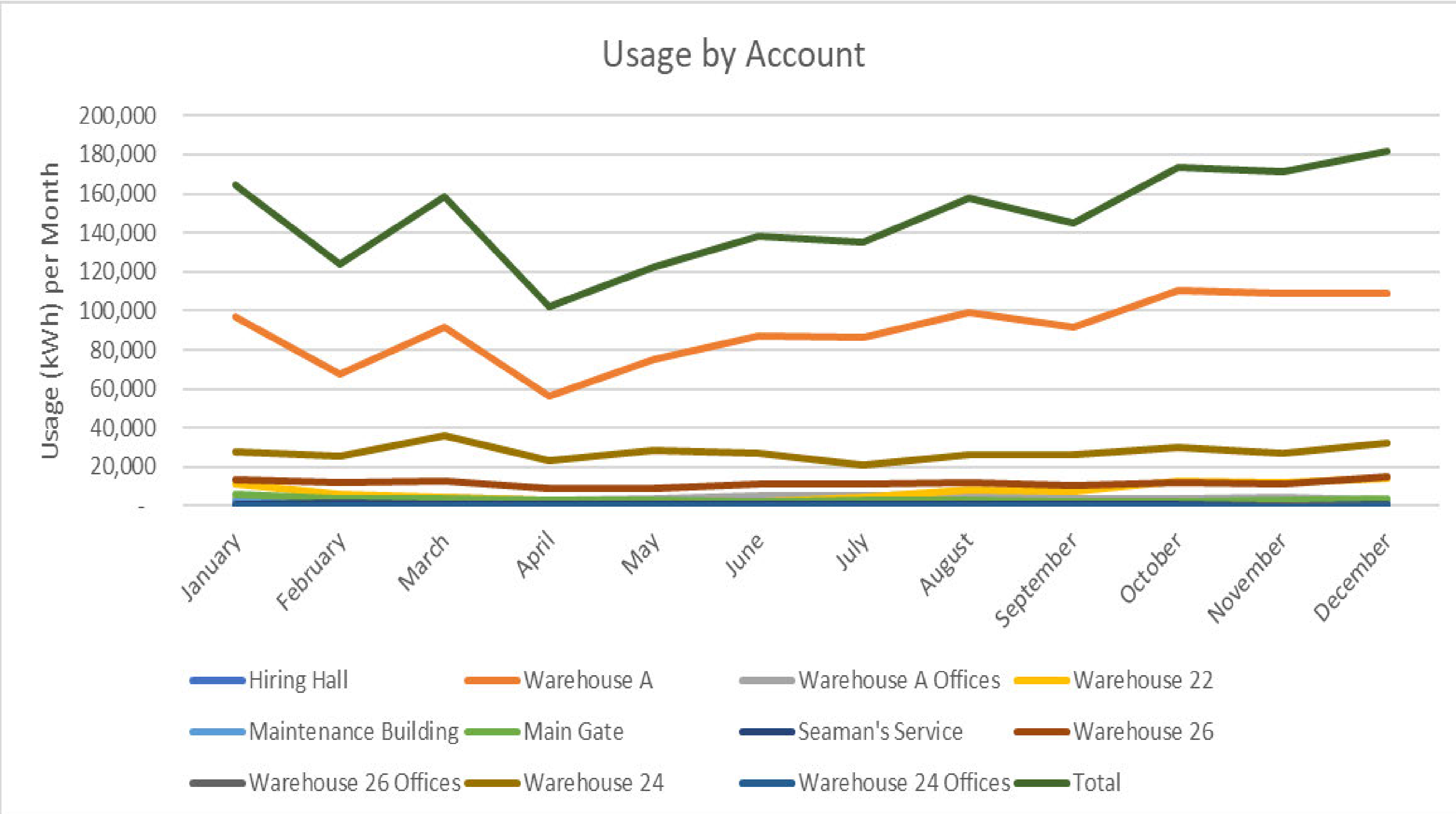


Figure 1-6. Baseline CPP Meter Data and Usage for 2022

Building	Hiring Hall	Warehouse A	Warehouse A Offices	Warehouse 22	Maintenance Building	Main Gate	Seaman's Service	Warehouse 26	Warehouse 26 Offices	Warehouse 24	Warehouse 24 Offices	Total
Billing Address	101 ERIESIDE AVE UNIT OUTBLD	695 ERIESIDE AVE UNIT BLD A	Warehouse A Offices	1103 ERIESIDE AVE	625 ERIESIDE AVE UNIT BLDG	425 ERIESIDE AVE	695 ERIESIDE AVE OFFICE GUARD	695 ERIESIDE AVE BLDG BLD26		695 ERIESIDE AVE BLDG BLD24		
Account Number	2481170000	1121641111		9086841111	6519641111	4224741111	3121641111	2121641111		121641111		
Meter Number	R23489	31K602			35A960	30K897	31K699	31K600		31K601		
Rate Schedule	Small Commercial	Large Commercial		Large Commercial	Small Commercial	Small Commercial		Small Commercial		Large Commercial		
Source	CPP Bills	Meter Reads	Meter Reads	Meter Reads	CPP Bills	CPP Bills	CPP Bills	Meter Reads	Meter Reads	Meter Reads	Meter Reads	
Month	Usage (kWh)	Usage (kWh)	Usage (kWh)	Usage (kWh)	Usage (kWh)	Usage (kWh)	Usage (kWh)	Usage (kWh)	Usage (kWh)	Usage (kWh)	Usage (kWh)	
January	2,968	96,960	3,331	10,960	2,256	6,240	600	13,440	97	27,440	140	164,432
February	2,586	67,600	3,302	5,680	2,035	4,040	1,120	12,120	107	25,360	142	124,092
March	1,940	91,760	4,351	4,240	1,939	3,760	960	12,920	123	36,280	165	158,438
April	861	56,320	3,193	2,800	1,997	3,320	880	9,000	84	23,400	112	101,967
May	602	74,880	3,905	320	1,927	2,760	560	9,000	79	28,560	114	122,707
June	756	86,880	5,425	1,840	1,877	2,440	680	10,960	136	27,280	135	138,409
July	708	86,640	5,148	4,480	2,378	2,680	440	11,440	122	21,120	117	135,273
August	895	99,200	5,586	8,160	2,323	2,880	480	11,880	127	26,200	119	157,850
September	511	91,840	3,883	7,520	1,802	2,480	480	10,160	84	26,360	113	145,233
October	555	110,320	3,611	12,480	2,369	2,520	480	11,640	62	29,720	123	173,880
November	1,393	109,120	4,371	11,760	2,178	3,160	200	11,480	97	27,040	102	170,901
December	1,776	108,880	2,978	14,000	2,383	3,960	440	15,040	132	32,320	154	182,063
Annual	15,551	1,080,400	49,084	84,240	25,464	40,240	7,320	139,080	1,250	331,080	1,536	1,775,245

1.4 Related Plans and Studies

A review of prior plans and studies is necessary to better understand the current climate change and green energy initiatives in Cleveland, and the greater Northeast Ohio region, and how these initiatives impact the Port of Cleveland's goals for achieving net zero-emission operations.

Our approach starts with the review of relevant studies, policies, and projects at the Port Authority and beyond, including local initiatives:

- *Port of Cleveland Strategic Plan Update 2017-2022* (Cleveland-Cuyahoga County Port Authority 2016), with a focus area in community and environmental assets and programs
- *Cleveland's Clean and Equitable Energy Future* (City of Cleveland 2021), developed by the Mayor's Office of Sustainability, core partners, and Greenlink Analytics. The plan establishes a future energy strategy with a focus on community equity, cost, and use of clean energy.
- *Cleveland Climate Action Plan 2018 Update* (City of Cleveland 2018), with a goal of transitioning 100 percent of Cleveland's municipal fleet, including CPP's fleet, to battery electric by 2035
- *Cuyahoga County Climate Change Action Plan* (Cuyahoga County 2019), which aims to increase the number of publicly available electric vehicle (EV) chargers throughout the county
- Plan published by the Northeast Ohio Areawide Coordinating Agency (2023) for the expansion of EV charging stations

1.4.1 Port Growth Areas and Master Plan Alignment

The shipping and break-bulk cargo industries play a vital role in global trade because they facilitate the movement of goods across regions. Understanding the macro trends shaping these sectors is vital for stakeholders to make informed decisions and adapt to evolving market conditions. The macro trends influencing these sectors include the impact of global trade patterns, technological advancements, regulatory changes, and sustainability initiatives. Appendix A further covers overarching global port trends.

Figure 1-7. Bulk Cargo Vessel Unloading at the Port of Cleveland, July 2023

The Port Authority is experiencing growth in the cruising and container ship industries (Figure 1-7), in addition to their existing bulk cargo business. Cruise ships used to thrive on the Great Lakes, but "with the growth of the U.S. highway system and regional airlines, all were gone by 1970" (Peterson 2023). However, cruise ship traffic has been on the rise in recent years, making a significant comeback in the area. The region attracts both domestic and international cruise operators that have been capitalizing on the growing interest in expedition-style cruises, which offer passengers a unique opportunity to explore lesser-known ports and destinations along the Great Lakes.

One significant milestone in cruise ship traffic growth on the Great Lakes was the launch of Victory Cruise Lines' *M/V Victory I* and *M/V Victory II*, which are purpose-built cruise ships designed to navigate the region's waterways. This development signified the growing interest and investment in the Great Lakes cruise industry.

"In 2022, the cruises drew nearly 150,000 passenger visits to the Great Lakes ports in the U.S. and Canada, a record, according to the industry group Cruise the Great Lakes. It forecasts nearly 170,000 visits in 2023 with an economic impact of $180 million" (Peterson 2023). In Cleveland, state funds from Ohio's Maritime Assistance Program and the city's central lake location have helped make the city a regular stop for cruise lines.

Similar growth can be claimed for the container ship traffic in the Great Lakes region. Historically, container shipping on the Great Lakes was limited due to the region's challenging geography of narrow channels and seasonal ice cover. However, with advancements in shipping technology and infrastructure improvements, the container shipping industry has seen steady growth in recent years.

The Port, situated on Lake Erie, has been at the forefront of container shipping in the Great Lakes region. This is because the Port has invested in expanding its container handling capabilities and improving intermodal connections to serve the growing demand for containerized cargo. Major supply chain disruptions at the East and West Coast ports in 2020 and 2021 led to main shippers looking for more efficient and direct access to the United States' Midwest. This has led to increased container ship traffic for the Port Authority, facilitating trade and supply chain efficiency for businesses in the region.

1.4.2 City of Cleveland North Coast Master Plan

The City of Cleveland is producing a master plan for Cleveland's lakefront areas. The comprehensive planning document serves to transform 14 miles of Cleveland's lakefront with guiding principles of racial equity, economic opportunity, and climate resiliency. It is evident that the City of Cleveland is prioritizing diversifying experiences and creating opportunities for the community along the city's waterfront. Simultaneously, the Port is experiencing fast-paced growth in multiple areas: shipping, cruise lines, and container shipping. The City of Cleveland and Port master planning efforts will work in parallel to enhance waterfront access and growth and create economic opportunity for the region.

The greatest impact of the North Coast Master Plan on the Port is aligning to best understand the vision for a future cruise terminal facility and the required infrastructure to support this new shared facility.

1.4.3 Cleveland's Climate Action Plan

Cleveland's Climate Action Plan, first released in 2013 and updated in 2018 (City of Cleveland 2018), prioritizes sustainable transportation to address climate change, improve air quality, and enhance mobility options. Key objectives include the following:

- Drive cleaner, more efficient vehicles
- Build transportation systems that prioritize safety for all
- Increase the use of public transit through regional collaboration
- Make Cleveland a premier cycling city
- Continue to green Cleveland's ports

The Climate Action Plan aims to reduce vehicle miles traveled, promote safe mobility, and achieve air quality attainment in Northeast Ohio by 2021. Most relevant is the objective set by the City of Cleveland to green the Port and actively pursue methods for emissions reduction for the Port's operations, which this master plan aims to identify.

1.4.4 Port of Cleveland's Strategic Plan

The Port's Strategic Plan update for 2017-2022 (Cleveland-Cuyahoga County Port Authority 2016) encompasses various lines of business, including maritime, development finance and real estate, community and environmental assets, and port administration. Based on data, analysis, and key findings, the plan proposes updated policies, actions, and key performance indicators to drive progress in each area.

To align with sustainability goals, the strategic plan recognizes the need for an electrification and net zero emissions master plan. This master plan will outline strategies for transitioning port operations to electric power, promoting renewable energy adoption, and achieving net zero emissions. By integrating this plan into the overall strategic framework, the Port demonstrates its commitment to following sustainable practices, reducing greenhouse gas (GHG) emissions, and contributing to a greener future for the Port and the surrounding community (Figure 1-8).

Figure 1-8. Cleveland Waterfront, Steamship William G. Mather, and FirstEnergy Stadium in Background

2. Infrastructure Development and Phasing

Long-term capital improvement planning, phasing, and budgeting is the key to the long-term success of any port operation aiming to transition its operations to zero emission (ZE). A methodical and stepped approach to piloting vehicles, chargers, and daily operational shifts is key to ensure that adequate training and budgeting is available. The electrification of cargo handling fleets is also capital cost intensive, so adequate funding and grant strategies must be implemented as well.

As illustrated on Figure 2-1, a broad scope of improvements to the Port of Cleveland's GCT facilities is planned to achieve ZE operations. Site infrastructure improvements include the consolidation of electrical service with CPP, as well as upgrades to 12-kV medium-voltage distribution across the GCT. In addition, the project phases include rooftop solar photovoltaic (PV) renewable power generation, EV charging systems for battery electric cargo handling equipment and support vehicles, cargo ship cold ironing at four berths, hybrid electric drive mobile harbor crane power connections, and the facility expansion of Warehouse A to accommodate modernized maintenance and education facilities.

Figure 2-1. Port of Cleveland Proposed Improvements

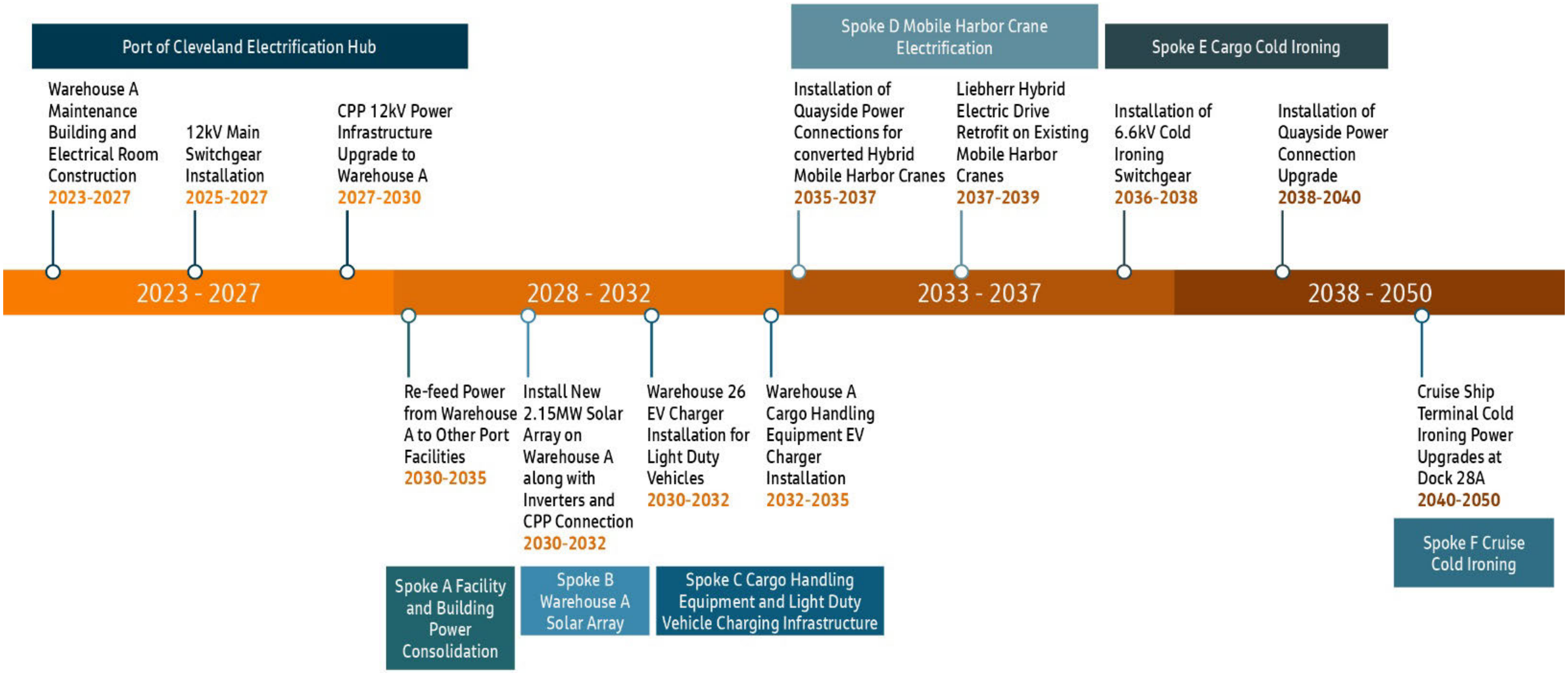
Successful implementation of ZE fleet transition is possible and feasible at the Port of Cleveland. To assist in the planning of this effort, a defined roadmap to infrastructure development at the Port's GCT was developed. To best prepare the Port of Cleveland for the future adoption of a battery electric fleet, it is recommended that subsequent projects and scopes are developed in a phased "hub-and-spoke" approach that allows the Port to easily build infrastructure elements as needed, in alignment with the adoption of battery electric equipment and funding availability. The hub-and-spoke model is characterized in the following list, as well as on Figure 2-2:

- **Port of Cleveland Electrification Hub (2023 to 2030):** A central connection point for all energy entering and leaving the Port's premises located within a large electrical room as part of the new Maintenance Building annex of the existing Warehouse A building. The new annex building will house a consolidated CPP incoming meter with a new 12-kV medium-voltage main switchgear. This represents a single point of connection to the CPP grid, and will be adequately sized to feed all other facilities and buildings within the Port in the future. The switchgear will have future provisions to accept future Warehouse A rooftop solar for renewable power generation. Additionally, the switchgear and incoming power feed from CPP will have the capacity to service future cargo ship cold ironing and battery electric cargo handling equipment charging needs. This project phase will involve the construction of a new maintenance building, a maritime education center, and a new main electrical room; crane upgrades, Warehouse A facility upgrades, and slab and pavement repairs; the installation of new 12-kV medium-voltage infrastructure from the CPP medium-voltage connection at the current U.S. Customs and Border Protection facility near the Port's main gate to Warehouse A; and new electrical distribution equipment.
- **Spoke A. Facility and Building Power Consolidation (2030 to 2035):** To maximize the cost benefits from CPP, it is recommended that all buildings within the Port of Cleveland have their power connections fed from the new hub main switchgear and thus be consolidated into a single point of connection with a single CPP meter and rate structure. This will also allow future Warehouse A solar power generation to service all other buildings at the Port during the day. This project phase will involve installing new buried electrical conduit and ductbanks from Warehouse A to each of the subsequent facilities onsite at the Port.
- **Spoke B. Warehouses A, 24, and 26 Solar Array (2030 to 2032):** An important element of a successful and economically viable electrification and net zero emission plan will be the installation and implementation of onsite renewable generation, specifically a solar PV array atop the roof of Warehouse A. Additional options for implementing additional solar could include deploying solar panels atop the roofs of Warehouses 24 and 26. Importantly, the onsite solar generation will offset the demand charges from CPP as a result of the increased electrical load due to battery electric equipment. This installation should be phased after the completion of the central electrical distribution hub, but before the installation of the EV charger equipment, mobile harbor crane, and cold ironing infrastructure of Spokes C, D, and E. This project phase will involve installing new structural solar panel supports atop the warehouse roofs, in conjunction with new membrane roofing systems, as well as new solar power inverter banks located inside the warehouses' envelope and connected to the main 12-kV switchgear in Warehouse A.
- **Spoke C. Cargo Handling Equipment, Switching Locomotive, and Light-Duty Vehicle Charging Infrastructure (2030 to 2035):** Electrifying the Port's cargo handling equipment and light-duty vehicles is the important first step to an all-battery-electric fleet to support the Port's operations and reduce direct tailpipe emissions. This project phase includes the extension of 12-kV electrical power from the main 12-kV switchgear located at the Warehouse A electrical room to a distributed network of direct current (DC) fast chargers installed alongside the east face of Warehouse A in order to support the heavy-duty cargo handling equipment fleet. Lower-power Level 2 electric vehicle supply equipment (EVSE) will also be installed at Warehouse 26 on a smaller scale to support the light-duty vehicle fleet.
- **Spoke D. Mobile Harbor Crane Electrification (2035 to 2039):** The existing mobile harbor cranes from Liebherr at the Port of Cleveland are good candidates to be converted with hybrid electric drives, allowing the cranes to load and unload while physically tethered to infrastructure power connections located at each of the cargo berths. The quayside power connection equipment installation for the mobile harbor cranes will be developed and installed in conjunction with the cargo cold ironing power connection equipment outlined in Spoke E, because the two power supply equipment types will be colocated alongside the cargo berths.
- **Spoke E. Cargo Cold Ironing (2036-2040):** This project phase includes deployment of cargo ship cold ironing connections along berths 24 and 26, installed in conjunction with new 6.6-kV electrical distribution equipment located at the Warehouse A main electrical room and fed from the 12-kV main

distribution switchgear installed as part of the initial Hub project phase. This project phase will involve the installation of new 6.6-kV feeders through the existing Dock 24 and 26 duct banks, along with procurement and installation of surface quayside mounted power connection equipment to meet the power needs of visiting cargo vessels.

- **Spoke F. Cruise Cold Ironing (2040 to 2050):** To develop cold ironing infrastructure capable of cruise ship calls to Dock 28A, new medium-voltage service from CPP will need to be installed from the CPP grid infrastructure surrounding FirstEnergy Stadium. Due to the large load requirements for large cruise ships, roughly 2.5 MW for ships the size of the *Viking Polaris*, this level of power availability is currently unknown and will likely not be able to be easily implemented until later phases of the overall electrification project at the Port of Cleveland. The infrastructure as part of this project phase will likely use a power connection point from CPP separate from the Warehouse A hub.

Figure 2-2. Implementation Timeline and Phasing



2.1 Site Electrical Distribution and Charging Infrastructure

The initial site electrical infrastructure improvement phases (Hub and Spoke A) are key elements of the long-term success of this plan, from a resiliency and economic standpoint. Working closely with CPP, the Port should update the decades-old 2.4-kV power distribution infrastructure, which was developed when the Port's GCT was a public roadway with dispersed warehouse operations. Given the current GCT layout, which includes a consolidated Port facility with a controlled main gate access, it is recommended that the Port adopt ownership of the medium-voltage electrical infrastructure within the GCT and establish a single 12-kV incoming electrical point of connection with CPP near the Port's existing main gate, fed from [redacted]. In addition, the Port can re-feed each building onsite with new 12-kV infrastructure, thereby consolidating all facilities at the Port's GCT under one CPP metered connection and rate structure. This provides future flexibility that allows the Port to install and operate behind-the-meter onsite renewable power generation in conjunction with DC fast charging for the equipment, vehicle, and locomotive fleet.

Prior to defining the recommended power level and size of charging infrastructure for the cargo handling equipment, switching locomotive, and light-duty vehicles, it was necessary to define the daily energy usage of each vehicle asset at the Port's GCT. Section 7 establishes that given the current fleet fueling consumption data, a battery electric version of every asset type is readily available and would be the recommended ZEV option. Importantly, it was determined that a battery electric version of the cargo handling and other support equipment would be able to complete a typical daily shift of work on one charge without the need for midday charging each day, although on the days that the Port operates overtime, charging midday and in the evening may be occasionally necessary.

Although battery electric technologies are preferred, given the Port of Cleveland's unique operational duty cycles, it is also important for the Port to be aware of other ZE technologies, such as hydrogen fuel cells, and the pros and cons associated with fuel cells. Appendices E and F provide an overview of hydrogen refueling types and infrastructure impacts, in addition to battery electric equipment charging technologies, architectures, and infrastructure considerations. An all-electric vehicle and equipment fleet at the Port will require a range of charging technologies and power levels to address the daily operational need of the various vehicles in use at the Port. These charging technology deployment is anticipated to be a part of the Spoke C project phase, following the installation of the necessary upstream electrical infrastructure. In Section 6 the baseline daily maximum energy being consumed in kilowatt-hours is established for each of the onsite diesel equipment. The assumed equivalent electric versions of the existing diesel equipment are also identified, along with battery pack size. This section will define the ideal charging power levels, EVSE architectures, and connector types for each equipment type to best serve its current duties. This section will also give an overview of the changes necessary to the existing driver and maintenance operation in order to transition from as-needed diesel fueling to daily overnight plug-in charging.

A centralized DC rectification charging architecture is preferred for the Warehouse A charging hub at the Port (Figure 2-3 and Figure 2-4). This is based on the identified EV equivalent battery sizes, the fleet quantities, and all the equipment being colocated in the same charging area on the east side of the warehouse. The preferred configuration is to deploy a medium-voltage-input, centralized DC charger skid with power output levels between 1.4 megawatts direct current (MWDC) and 2 MWDC. This would provide adequate power for all cargo handling equipment on site, while taking up a relatively small amount of space.

Using a medium-voltage (12 kV) input voltage for the charger inverter cabinets instead of the standard 480-V input will allow the Port to reduce the number of transformers needed on site and take advantage of a lower electrical purchase rate from CPP.

To develop accurate cost examples and spatial layouts and ensure that assumptions made within this section are grounded based on equipment available for purchase today, Jacobs has selected a representative EV charger product to illustrate power levels, dispenser distribution, and possible configurations to charge the Port GCT fleet. These recommended chargers by vehicle type and use are further elaborated in Appendix G. In addition, to help guide future planning and design phases, Jacobs has created a conceptual design showing the envisioned operations of the charge points and forklifts at the Warehouse A charging hub, as part of planned phase Spoke C and as depicted on Figure 2-3 and Figure 2-4. Figure 2-3 depicts an elevation view of the east face of Warehouse A and illustrates the charging setup, featuring a raised walkway that facilitates heavy-duty forklift charging through a charging dispenser equipped with 30-kilowatt (kW) CCS1 DC charging connectors.

Figure 2-3. Warehouse A Charging Hub Forklift Charging Station Design (Elevation View)

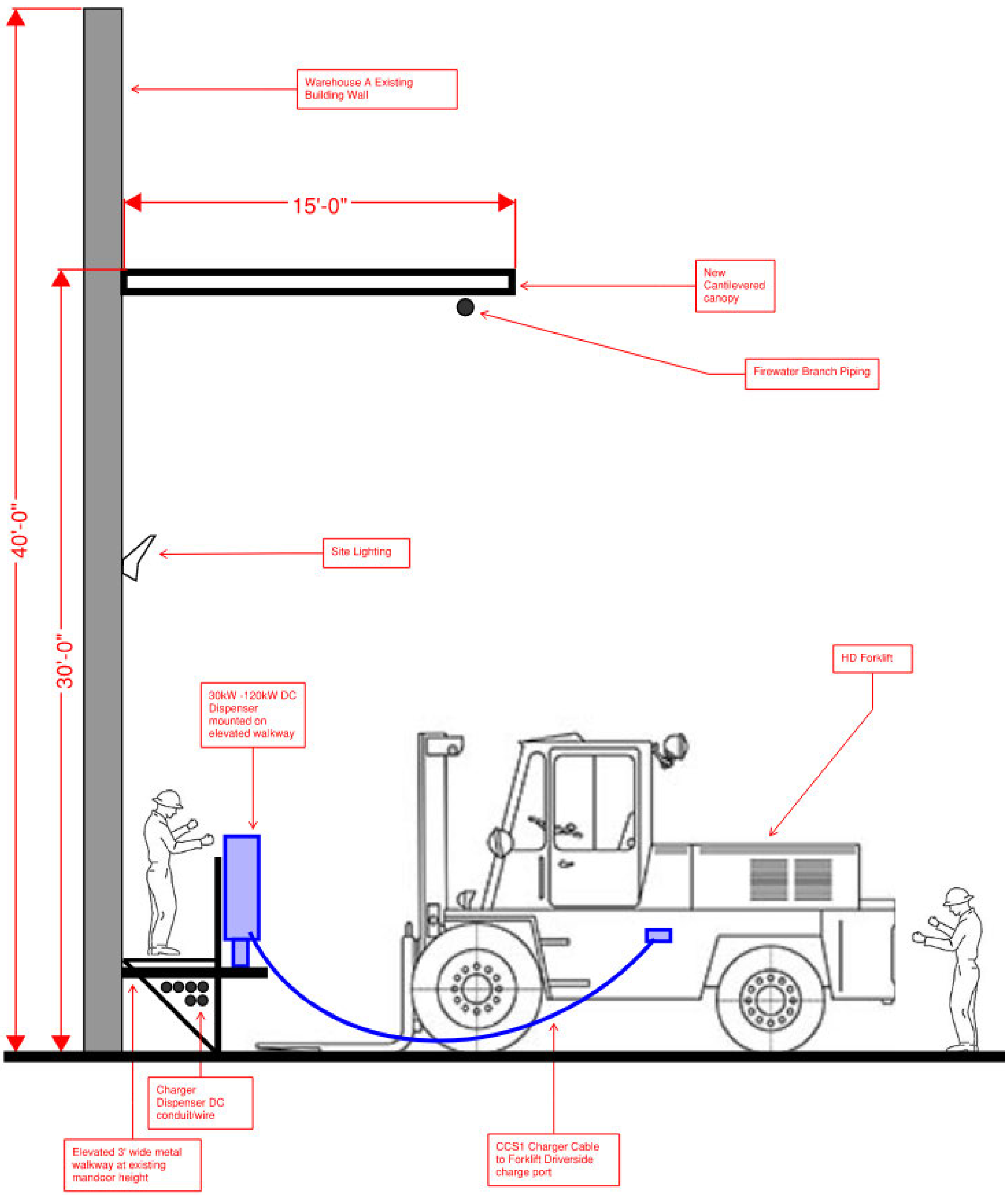
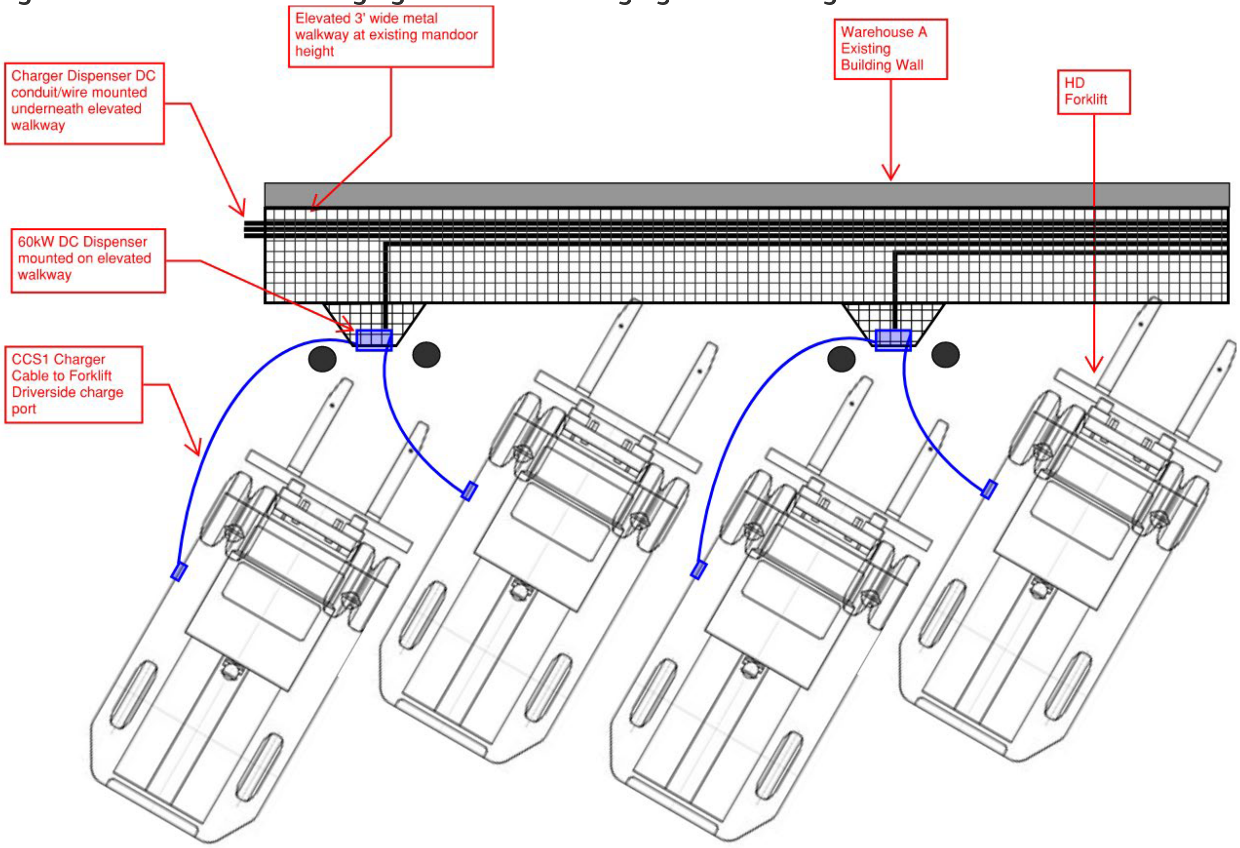


Figure 2-4. Warehouse A Charging Hub Forklift Charging Station Design



3. Operations and Maintenance Impacts and Recommendations

3.1 Operations and Maintenance

When transitioning a fleet to ZE technologies, the operations and maintenance of both the fleet and the infrastructure require a completely different approach from that of the current diesel-fueled vehicles and vessels. Once the infrastructure is installed, there are several operational considerations such as electricity and maintenance costs, pavement markings and signage to designate reserved parking for ZEVs, charging schedule, and data collection. With the right approach and technology, challenges associated with the transition to ZE technologies can be overcome. In general, it is recommended that the Port develop an operation and maintenance plan for its ZE fleet to address service planning, training, and maintenance protocols.

3.1.1 Assumptions

Jacobs performed numerous site visits to observe and survey the existing cargo handling fleet's patterns, both during shift and off shift. Notably, observations were made during days of peak loading and unloading activity in July 2023, as well as off days with no ships at the Port.

The EVSE locations are proposed to be placed against the east side of the existing Warehouse A facility, which is adjacent to the majority of the equipment's existing operating areas and the new proposed maintenance building annex. This location provides the closest proximity to incoming CPP electrical infrastructure. Additionally, the proposed EVSE configurations and locations will provide designated parking areas for cargo handling equipment away from truck and railcar movements.

The cargo handling equipment at the Port currently does not have dedicated parking areas and is currently parked in various locations around each warehouse area when not in use, both during off days and overnight. Although the implementation of hydrogen-fueled cargo handling equipment would not change the current operating practices, due to fueling of fuel cell vehicles being relatively similar to how the current diesel fleet is refueled, a transition to battery electric vehicles will require further planning. A deployment of electric cargo handling equipment at Port will require the vehicles to be parked at the same assigned locations with EVSE each day to recharge. Certain smaller vehicles, such as the forklifts, will use a certain parking stall and charger size, whereas the larger vehicles, such as the container handlers, will need to park and charge at a dedicated stall that is larger and has a higher-output charger. Day-over-day operational processes will need to be implemented to ensure that each vehicle reaches its assigned stall and charger type each night to ensure a full day's battery charge the next day.

To ensure that the vehicles are parked at assigned locations and chargers, existing staff and drivers will need to be trained. The Port operates with a rotating workforce on day-long contracts with the local union, and employed by Logistec, the current contracted tenant. The operators and drivers of the cargo handling equipment can vary day over day, and it is assumed that it would be infeasible to effectively train the incoming drivers on the proper operation of a charging station, including how to plug in a vehicle and initiate a charge session. It is recommended that the terminal operator bring on additional full-time staff, permanently or temporarily, as necessary to ensure proper training of the driver staff interacting with and operating the charger systems. This conceptual role is still in its infancy as battery electric equipment are deployed and come to market. This arrangement is not currently being used at other ports, but this concept is being used today within the transit bus and similar transportation industries to ensure that daily uptime and charging requirements are met, when the union driver/operator pool changes from day to day and charger operation training for drivers is difficult or infeasible.

The new trained full-time staff members are envisioned to potentially perform the following daily tasks, among others, to ensure seamless usage of the Port-owned charging infrastructure:

- Monitor charger statuses and faults during the overnight charging window from a centralized control screen and room within the new maintenance building.
- Reset chargers and faults as needed.
- Engage with charger manufacturers over warranty, service issues, and fault resolution.
- Assist drivers with pulling in and aligning the vehicles into the charging stalls at the end of each shift.
- Manually plug in the vehicles at the end of shift and ensure successful charging session start.
- Move vehicles around at night, as necessary, to ensure that all vehicles are charged for the beginning of each shift.
- Unplug vehicles and ensure the vehicles are fully charged at the beginning of each shift.

Additionally, the operational shift to battery electric vehicles will ultimately introduce new risks and changes to the current way of doing work at the port. During loading and unloading days, battery electric vehicles will need to charge each evening to ensure fully charged batteries at the start of the next day's shift and meet the Port's operational needs and requirements. A potential scenario to illustrate this risk is when a faulting charger overnight leads to an inability for a forklift or reach stacker to perform the needed loading and unloading tasks, and a vessel must layover longer than it normally would at berth. In this scenario the question is: what entity would be responsible for the incurred costs due to this issue? Although this is a new concern within the Port and maritime industry, there are many parallels from the public transit bus agency industry, because that industry has adopted battery electric buses and still has uptime and service requirements. Generally, the entity using and monitoring the charger, not the charger owner, and specifically in this case the operator/contractor entity that is employing the new staff members dedicated to plugging and unplugging and monitoring the charger stations at night, would be responsible to ensure that the equipment is fully charged and chargers are functioning as intended. Some strategies for this entity to mitigate the risk and exposure would be to have additional cargo handling equipment on standby, or additional charger stations available to buffer the fleet if a charger or multiple chargers fault and are down. Having a fast high-power charger available for midday lunchtime charging is also a good strategy to ensure that a vehicle who is not 100 percent charged at the beginning of the shift can still fulfill the daily shift operational needs. At Warehouse A, the locomotive is anticipated to use a 360-kW fast charger, but that would be used only occasionally and typically at night; a forklift or container handler could use that same charger for fast midday charging if needed. The availability of the charging equipment, as well as access to the chargers themselves, should be further explored to ensure that midday charging by cargo handling equipment does not interfere with the Warehouse A coil loading/unloading operations.

In addition to the day-to-day processes that will need to be implemented to de-risk any productivity shortfalls, it is also important to understand the Port Authority's seasonal operating window and how that factors into a transition to ZE cargo handling equipment and cold ironing. Generally, the cargo handling and cruise ship operation at the Port is seasonal by virtue of its location along Lake Erie, and thus subject to changes in usage of the cargo handling fleet based on the month of the year. The annual shipping season in which the Port accepts ship calls runs from the beginning of April to the end of December, an estimated 250 working days (averaged with federal holidays over 10 years), with all ship cargo unloading activities occurring during this time. From late December to late March, the Port is largely shut down to ship traffic and operations are confined to limited forklift warehouse usage to move and store cargo within the Port's three large warehouses during the winter months. It is assumed that forklifts, reach stackers, yard tractors, and light-duty trucks and SUVs at Port operate year-round, averaging 250 working days per year (averaged with federal holidays over 10 years). All other equipment, such as the mobile harbor cranes, switching locomotive, and work barges are assumed to be used only during the summer/fall operational months, equating to 187 working days (averaged with federal holidays over 10 years), and is parked in storage during the winter offseason months. A major concern is how the efficiency of ZEVs changes over the seasons, specifically on colder-weather days. Appendix B provides more details on the inherent efficiency losses of both hydrogen and battery electric vehicle operating in cold winter climates and temperatures. Cold ironing loads from shipping and cruise lines will also occur only within the 187 working days of the summer/fall operational season.

The Port typically operates 8-hour days with normal working hours 7 a.m. to 4 p.m. and a 1-hour lunch break, 5 days per week, Monday through Friday. When a ship is being offloaded onsite, the Port may operate cargo handling equipment over weekends, but that is assumed to be occasional and not typical. It is assumed that battery electric vehicles and equipment will be able to charge overnight with a dwell time of a maximum of 15 hours from 4 p.m. to 7 a.m. To ensure an operational buffer for charging both before and after each shift, 12 hours of overnight dwell time was assumed in the vehicle energy and charging calculations. Usage of charger management software will also allow the majority of the fleet's charging window to overlap with the discounted CPP "off-peak demand" period from 12:00 a.m. until 8:00 a.m. on weekdays. Table 3-1 summarizes the utilization assumptions used for this analysis.

Table 3-1. Utilization Assumptions

Utilization Assumptions	
Days per Year	250
Days per Week	5
Hours per Day	8
Hours to Charge per Day	14

The following working-hour assumptions were made to develop the charging scheme, in addition to assumptions defining the number of working days per year for each piece of equipment (Table 3-2).

Table 3-2. Working-day Assumptions by Vehicle Type

Vehicle and Equipment Type	Working Hours	Working Days per Year	Description
Forklifts	7 a.m. to 4 p.m.	250	Yearlong, Monday through Friday working days
Reach Stackers	7 a.m. to 4 p.m.	250	Yearlong, Monday through Friday working days
Yard Tractors	7 a.m. to 4 p.m.	250	Yearlong, Monday through Friday working days
Mobile Harbor Cranes	7 a.m. to 4 p.m.	187	April through December, Monday through Friday working days
Work Barges	7 a.m. to 4 p.m.	187	April through December, Monday through Friday working days
Switching Locomotive	7 a.m. to 4 p.m.	187	April through December, Monday through Friday working days
Light-duty Trucks and SUVs	7 a.m. to 4 p.m.	250	Yearlong, Monday through Friday working days
UTV	7 a.m. to 4 p.m.	250	Yearlong, Monday through Friday working days
Manlift	7 a.m. to 4 p.m.	250	Yearlong, Monday through Friday working days
Generator	7 a.m. to 4 p.m.	250	Yearlong, Monday through Friday working days
Wheel Loader	7 a.m. to 4 p.m.	250	Yearlong, Monday through Friday working days

3.2 Port and Contractor Engagement

This section aims to provide a high-level opinion on potential options for the Port to engage with the Contractor on the subject of EVSE ownership, maintenance, and servicing.

There are two root models for EVSE ownership: self-owned or leased. These two options can be applied to either the Port or the Contractor, considering technology maturity and development, commercial, and potential incentive aspects.

- **Self-Owned Model**
  - **Ownership:** Equipment can be owned by either the Port or the Contractor.

- **Maintenance/Service:** Can be undertaken by (i) the Port/Contractor, or by (ii) third-party outsourced service.
- **Operation:** Operated by the Contractor.
- **Commercial:** (i) One-time capital expenditure burden by the owner, (ii) lease revenue to the Port if leased to Contractor, (iii) lower finance recurrent costs.
- **Risks:** (i) Owner left behind with technology advancement due to locked ownership, (ii) ownership cannot be enforced on Contractor, (iii) contractor resistance to own due to Stevedoring Contract terms and duration, (iv) higher exposure to maintenance issues and aging equipment/spare availability/battery issues.
- **Opportunities:** (i) Additional revenue to the Port if leased to Contractor, (ii) Stevedoring Contract lease terms update, (iii) incentive scheme opportunities.

▪ **Lease Model**

- **Ownership:** Equipment owned by leasing company.
- **Maintenance/Service:** Can be undertaken by (i) the Port/Contractor or by (ii) third-party outsourced service from the leasing company.
- **Operation:** Operated by the Contractor.
- **Commercial:** (i) No capital expenditure burden for the Port/Contractor, (ii) higher finance recurring costs, (iii) requires the Port/Contractor to engage leasing company.
- **Risks:** (i) Lower technology advancement risk, (ii) no risk of ownership, (iii) lower Contractor resistance to lease due to Stevedoring Contract terms and duration, (iii) lower exposure to maintenance issues and aging equipment/spare availability/battery issues.
- **Opportunities:** (i) Additional revenue to the Port if leased to Contractor, (ii) Stevedoring Contract lease terms update, (iii) incentive scheme opportunities.

Overall, at this early stage of technology adoption, the lease model for this type of technology and commercial stevedoring engagement provides less risk in terms of ownership and long-term commitment. The lease model provides flexibility and technology adoption windows, but at a cost.

We would recommend a cost-benefit analysis of the options, considering key commercial stevedoring aspects and their risk derivates, to develop a more detailed analysis to support the decisions to be made. The Port can approach individual original equipment manufacturers (OEMs) and leasing companies from the industry to explore different options and models on equipment and maintenance service contracts, and in parallel explore with the Contractor their acceptance of such models, considering also their commercial interests and relationship with the Port. The long-term lease pricing from this leased model for the battery electric equipment could then be a "pass-through" cost to the Port's Contractor. This scenario would also enable the Port to retain the same equipment onsite during the transition from one Contractor to another, as well the ability to source and select the third-party leasing company of the Port's choice, potentially with a longer-term lease than the Contractor contract length.

In either model, the Port will have to develop individual incentives to back the model to negotiate with the Contractor the most beneficial solution to the parties. Incentives include reduced port equipment rent to the Contractor, rebates from the power company by using green technologies, discounted energy charging rates, and longer stevedoring contract durations.

3.3 Workforce Development

Workforce development and training will be imperative for a successful transition and long-term stability of ZE practices. The rapid growth and adoption of EVs have prompted a need for well-trained professionals capable of operating and maintaining the charging infrastructure. It will be important for the Port to invest in comprehensive training programs that equip its workforce with the necessary skills and knowledge. The transition to electric equipment presents a unique opportunity to use existing staffing levels, with little to no headcount impacts.

The Port may consider internal training, market available training programs, or likely a combination of the two. There are several training programs available in the market that support workforce training specific to EV operations and maintenance. Many of these programs cover high-level overview topics such as systems and components, maintenance and inspection, and diagnostic tools and troubleshooting, whereas some programs offer additional areas of focus and specialization. These training programs include manufacturer-specific programs, automotive industry associations, vocational/technical institutions, training centers, online platforms, and government/utility programs. Each type of program is briefly summarized as follows:

- Many EV manufacturers offer training programs tailored to their specific vehicle models. These programs provide in-depth knowledge of the manufacturer's EV systems, including battery management, charging infrastructure, and vehicle diagnostics. These programs often cover areas such as vehicle inspections, maintenance procedures, and software updates. Two key areas to ensure are covered under maintenance are relevant training on electrical safety and electric power troubleshooting. Manufacturer-specific training programs would be beneficial with a fleet consisting primarily of vehicles from a specific manufacturer. A specific certificate that would be valuable for the Port's technicians is the Certified Electric Vehicle Technician certificate program designed to train a new generation of EV specialists to work in EV production, repair, and maintenance.
- Vocational and technical institutions also offer comprehensive training programs for EV operations and maintenance. These programs typically provide a well-rounded curriculum encompassing EV technology, safety procedures, charging infrastructure, and maintenance practices. Examples of institutions offering EV training include community colleges, trade schools, and vocational training centers. These programs often combine theoretical coursework with hands-on training, ensuring practical skills development.
- As to be expected, online platforms have also emerged as a convenient and accessible option for EV training. Various e-learning platforms offer specialized courses and modules related to EV operations and maintenance. These courses typically consist of video lectures, interactive simulations, and assessments. Online training allows companies to provide flexible learning opportunities for their workforce, accommodating different schedules and locations.
- Government agencies and utility companies often develop training programs to support the adoption of EVs. These programs aim to train technicians, fleet managers, and other professionals in EV-specific skills. Examples include the U.S. Department of Energy's EV Everywhere Workplace Charging Challenge and various utility-sponsored programs. These initiatives provide valuable resources, webinars, and workshops to enhance workforce knowledge in EV operations and maintenance.
- Additionally, there are several training programs and statewide initiatives offered in Ohio. For instance, Ohio State University's Center for Automotive Research offers various programs and workshops related to EVs and advanced automotive technologies. Sinclair Community College, Cincinnati State Technical Community College, and Cuyahoga Community College offer courses and training programs on EV maintenance and repair. The Port could leverage these local training programs. A more comprehensive list of EV-relevant advanced manufacturing education program is provided as follows:

  - Auto Technology Program – Mahoning County Career and Technical Center
  - CNC Advanced Manufacturing Technologies – Great Oaks Career Campuses
  - Dept of Engineering; Advanced Manufacturing Lab – Otterbein University
  - Dept of Engineering – Lorain County Community College
  - Electro-Mechanical Engineering Technology – Columbus State Community College
  - Manufacturing Skills and Continuing Education – Butler Tech
  - Programmable Logic Controllers Certificate – Eastern Gateway Community College

Recently, Ohio developed an Electric Vehicle Workforce Roadmap that outlines its strategy for EV adoption, charging infrastructure development, and related initiatives. The Roadmap established three action pillars to bolster its EV workforce including driving EV industry desirability and career awareness, broadening the EV workforce talent pool, and scaling education and training to meet EV demand. Key activities are associated with each action pillar to deliver outcomes that grow Ohio's workforce.

To conclude, these are several market-ready training programs and statewide initiatives available to aid the Port in training its workforce. It is recommended that the Port partner and assign training vendors to accomplish its training goals. Additionally, the Port should incorporate training costs in the fiscal year budget.

3.4 Billing and Energy Tracking

Tracking and documenting energy usage data for the fleet is critical to EV deployment, and to sustaining the business model for the Port, in which the Port sells energy via the DC charging systems to the contracted tenant as the tenant recharges the equipment during normal operations. An advanced meter at the incoming switchgear serving the charging systems will allow for real-time monitoring and collection of data (including interval data) for the electrical consumption of the charging systems. However, the metering setup by itself will not allow electrical consumption by different users at the charging site to be tracked. If a vehicle plugs into a charging system at the site, its consumption data are included in the total site consumption, but no additional granularity is provided. Therefore, it is recommended that the charging systems have smart charging and billing software to provide additional capabilities, including:

- Tracking typical energy usage by vehicle type, size, and class.
- Tracking energy usage by vehicle and driver to ensure electricity costs are billed correctly.
- EVSE energy curves and software that can tailor the EVSE energy demand to stay under set energy usage caps.
- Vehicle telematics data integration to optimize fleet charging scheduling.
- Facilitating billing transactions in real time from the Port (owner) to the contracted tenant company.

Charging system cloud-based management software enables effective oversite and control of the charging system network. A fleet manager can log in and view energy usage data via a cloud-based Internet dashboard. The dashboard enables users to obtain an overall view of the health and operating parameters of the entire charging system network through a concise and user-friendly interface. Cloud-based subscriptions have key features such as high-level power use caps, fault monitoring, and tracking of vehicle charging sessions for billing and reporting purposes. The cloud-based management system provides real-time monitoring and maximum power usage setpoints to prevent demand beyond the cumulative connected load rating of the electrical distribution system and equipment. Automated reports available with most of the major charging system networks can produced preconfigured energy use, cost, and emission reduction reports. In addition, most of the cloud-based systems allow users to create custom reports to meet reporting needs. For the Port, data cybersecurity and cloud-connected service restrictions relating to rules from the Transportation Security Administration, Federal Transit Administration, and U.S. Department of Transportation Maritime Administration may significantly limit the use, functionality, and benefits of cloud-based management software.

3.5 Maintenance of Equipment and EVSE

The Port currently manages facilities and some specialized equipment, such as the mobile harbor cranes and reach stackers, but generally the third party private terminal operator contractor owns, operates, and maintains the majority of the cargo handling equipment fleet. It is envisioned that the Port would purchase new battery electric equipment outright, with a private contractor operating, charging, and maintaining the equipment on a daily basis. The contractor's maintenance of battery electric equipment could either be included in the yearly contract as part of operations, as a separate annual maintenance contract with specialized EV and EVSE maintenance partners, or where the Port contracts to a wholly different entity for maintenance of the equipment and EVSE that is separate from the operations contractor. This section overviews the crucial aspects of planned maintenance, unplanned maintenance, and consumables related to battery electric equipment and EVSE operations and maintenance.

General maintenance and servicing of battery electric equipment supporting EVSE can vary greatly in terms of the technical skills required by the technician. Basic preventative maintenance activities can typically include cleaning of the equipment, changing of filters, inspection of electrical connections, and storing charging cables securely. In other situations, the chargers may need intermittent repairs involving removing and replacement of power electronics, power inverters, and other critical components due to electrical damage, water intrusion, or part failure.

The maintenance strategy should aim to implement a “right tool for the job” mentality, where specific classifications and tiers of technicians and technician training are implemented to ensure a robust pool of resources to meet required response times that are scalable through the larger equipment deployment phases.

4. Safety and Resiliency Considerations

Common concerns surrounding both hydrogen and battery electric land-based cargo handling vehicles are that of increased risk, encompassing safety, fire risk, cybersecurity concerns, and end-of-life battery recycling. Additionally, resiliency is a common concern, and addressing the question "What happens when the grid fails?" should be a focus area for any ZE equipment fleet operator developing a transition plan. This section will overview common topics, concerns, risk, and methods to de-risk the Port Authority's operation for the coming decades.

4.1 Fire Safety

Battery EVs are inherently less combustible than diesel-fueled variants, but lithium-ion battery fires burn differently and must be extinguished with different methods. Generally, thermal runaway events within battery fires are caused by electrical safety system failure or cooling system failure, or both. To extinguish a battery fire, large volumes of water must be used and applied over a substantial window of time to ensure that the water has penetrated the battery pack sufficiently and that the cells within are adequately cooled.

It is recommended that all electric equipment be primarily charged and stored outdoors at locations noted in this report to minimize fire protection study work on the building's existing fire protection systems. One exception is the future planned battery electric rail switching locomotive, which is currently stored within Warehouse A and is planned to be stored there in the future. In this instance it is recommended that the overhead sprinkler system's flow rates, for the bays immediately above the rail locomotive, be increased to 0.7 gallon per minute, and adequately reviewed by a fire protection engineer. All other overnight charging areas to serve the cargo handling equipment should be located outdoors away from combustible/flammable materials and away from stored materials and goods. In the instance of vehicles being stored, maintained, and charged via mobile chargers in the maintenance building, it is recommended that a fire study be performed to determine the necessary sprinkler system upgrades for storing EVs.

4.2 Power Resiliency

The transition to EVs increases the Port's reliance on the electrical grid, which results in an increased risk of operations being impacted during power outages. To mitigate this risk, power resiliency measures should be considered and evaluated based on critical and emergency operational needs.

Permanently mounted natural gas–powered linear generator technologies present an ideal solution, as they use existing natural gas infrastructure and can produce clean power with minimal harmonics that is suited for direct supply to DC EVSE systems. These linear generator systems also have the ability to produce low levels of nitric oxide emissions and are easier to permit from an air quality standpoint. Generators require ongoing maintenance, whether the generators are actively used or not.

Smart charging is vital to maintaining operational resiliency. With telematics and a charging management system, the Port can determine which charging systems are critical to maintain during emergency operations and concentrate backup power on these specific charging systems.

The strategies employed are mostly dependent on the required uptime of the operational fleet. While some fleets may require only a defined amount of time, such as 24 hours, for charging emergency backup, it can be assumed that long-term electrical grid resilience is needed to support the Port operations.

4.3 Cybersecurity

As with many new technological advancements, EV charging is subject to cybersecurity threats. In general, the whole system surrounding the charging station, the vehicle, and power grid also pose cybersecurity considerations. Specific to charging stations, a cybersecurity attack could impact the station itself as well as the vehicle control system and any infrastructure connected to it. Additional risks include new attack vectors for the U.S. electric grid, loss of customer data such as personal and financial information, and control of the EVSE physical system through the Internet, which may offer a foothold to internal enterprise networks. One reason for this is because charging stations are being developed quickly and are connected to both the Internet and the vehicle. Valuable personal data (including location, behavior, and billing details) are transferred using physical and wireless connections.

On a broader scale, EV charging systems present the possibility of both local and widespread impacts. Local impacts could occur due to the failure to charge vehicles, damage to batteries or other EV components, compromised EVSE life-safety systems, loss of EVSE service availability, and theft of personal and financial information. Large-scale impacts could occur due to the shutdown of entire EVSE charging networks, exposure of upstream and partner information technology networks, misconfiguration of EVSE that creates damaging or dangerous conditions, loss of consumer confidence in EVSE systems, and bulk power system impacts.

The transition to battery-powered vehicles increases the Port's reliance on the grid, which results in an increased risk of power outages impacting operations. To mitigate this risk, power resiliency measures should be considered and evaluated based on critical and emergency operational needs. Power resiliency can be established through a means of onsite energy generation, such as a solar canopy with battery storage system to serve as a backup for the EV chargers. The use of microgrids and backup generators can also be considered because many generators currently exist onsite and can be transitioned to ZE technologies as well. In addition, smart charging is vital to maintain operational resiliency. With telematics and a charging management system, the Port can determine which chargers are critical to maintain emergency operations.

4.4 Spare Battery Pack Storage and Recycling

Generally, due to battery pack cell degradation over time, it is recommended that battery packs for the battery electric cargo handling equipment be replaced mid-life. This costs for hardware and labor to perform these battery pack replacements are typically built into the standard long-term leasing terms for a heavy-duty battery electric vehicle and would be performed by the leasing company and/or vehicle OEM. Although these battery pack replacement activities will be performed by the leasing company, and not the Port or the Port's operator, it is still critical that adequate facilities are developed on site to accommodate the storage of spare battery packs and the necessary maintenance facilities and overhead cranes to facilitate the mid-life battery pack replacement without needing to transport the equipment offsite. The Port could also facilitate the introductions of local battery recycling companies in Ohio to ensure that the battery packs requiring disposal are staying within the general circular economy of the surrounding areas.

With the increased demand for and use of individual and mass transit EVs, a concern is growing over the long-term environmental and cost impacts that these battery packs have on our society. Often, these non-biodegradable batteries end up in landfills, contaminating the soil and groundwater with heavy metals and flammable/toxic electrolytes over time. At of the end of 2017, 95 percent of lithium-ion batteries were either stockpiled or sent to landfills when they reached the end of their useful life. With only 5 percent of lithium-ion batteries being recycled, the International Energy Agency predicts that by 2030, EVs alone could leave up to 11 million lithium-ion batteries that need to be recycled. Previously, only about 30 to 40 percent of lithium material could be extracted from a battery for recycling. With new smelting innovations funded by the Swedish Battery Fund, nearly 100 percent of lithium-ion battery material can be recycled and reclaimed. Environmental prudence and financial returns are not the only motivating factors behind recycling of lithium-ion batteries.

The Inflation Reduction Act (IRA) of 2022 introduced several provisions relating to the inherent value of recycled batteries and their mineral components. Most of these are contained in the "Advanced Manufacturing Production Credit" provisions of the Act, called IRA Section 45X. The Production Tax Credit

(PTC) applies to the cathode, anode, and other critical battery materials typically used in lithium-ion battery packs, specifically if the vehicle contains critical materials that were mined, processed, or recycled in the United States or in a country in which the United States has a fair trade agreement with, or if the materials were recycled in North America. The last provision on North America battery recycling promises to have a significant impact on the growth of battery recyclers in the United States, decreasing the costs of extracting minerals from used battery packs, as well as the availability of services for fleet owners. As of 2023 there exists a good number of recycling companies in the United States for the purpose of recycling commercial battery packs, notably Redwood Materials in Reno, Nevada, and newer entrant to the market Cirba Solutions in Lancaster, Ohio. Cirba Solutions currently operates six battery processing facilities in North America with additional planned growth. In Lancaster, Ohio, roughly 25 miles south of Columbus, Ohio, Cirba Solutions operates a dedicated lithium-ion battery recycling facility capable of processing millions of pounds of batteries each year. Typically these end-of-life battery recycling programs are implemented by the vehicle OEM, which would have agreements in place with a recycler like Redwood Materials and Cirba Solutions. As the Port of Cleveland solicits and procures battery electric vehicles and equipment, it is important to ensure that the OEM supplying the equipment has an end-of-life recycling cost built in to ensure that the batteries are disposed of properly and with a clear chain of custody. Costs of battery recycling borne by the client vary greatly in today’s markets, but can be in the range of $20 to $80 per kilowatt-hour (kWh).

5. Environmental and Emissions Reduction

The urgent need for emissions reduction in ports stems from their significant environmental impact on local ecosystems and human health. Ports are notorious sources of air pollution due to the heavy reliance on diesel-powered ocean-going vessels, harbor craft, heavy-duty trucks, cargo handling equipment, and rail locomotives associated with Port activity.

The resulting emissions, known as criteria pollutants, surrogates and precursors, diesel particulate matter (DPM), and fuel combustion-related GHG emissions, contribute to air quality deterioration, respiratory illnesses, and climate change. Table 5-1 lists the exhaust emissions of various pollutants that are estimated in this section. Currently, the maritime sector accounts for approximately 2.8 percent of all global GHG emissions. This is largely due to rapid growth, dependence on carbon-intensive bunkers, and the sheer size of maritime business as it is responsible for transporting 80 percent of the world's goods by volume and over 70 percent of global trade by value (UNCTAD 2022). By implementing emissions reduction measures such as adopting cleaner fuels, electrifying port operations, and optimizing logistics, ports can play a crucial role in mitigating their ecological footprint, improving air quality for nearby communities, and safeguarding cities and the planet for future generations. Therefore, it is critical to know the current emissions profile of the sources mentioned previously.

Table 5-1. Primary Maritime Sector Exhaust Emissions

Criteria Pollutants/Surrogates/Precursors	Fuel Combustion-Related GHGs	DPM Examples
Nitrogen oxides (NO_x)	Carbon dioxide (CO_2)	Fine particles released during diesel fuel combustion
Particulate matter (PM) ($PM_{2.5}$ and PM_{10})	Nitrous oxide (N_2O)	Visible black or grey smoke emitted from diesel vehicle tailpipes
Volatile organic compounds (VOC)	Methane (CH_4)	Dark residue accumulating on surfaces exposed to diesel exhaust
Carbon monoxide (CO)		Collected particles in diesel particulate filters (DPFs)
Sulphur dioxide (SO_2)		Fine particles causing indoor air pollution from nearby diesel exhaust sources

PM_{10} = particulate matter measuring 10 microns in diameter
$PM_{2.5}$ = particulate matter measuring 2.5 microns in diameter

Throughout this section, GHG emissions are measured using carbon dioxide equivalents (CO_2e), which accounts for the global warming potential of each gas. The GHG emissions for different gases are multiplied by their respective global warming potential values (1 for CO_2, 298 for nitrous oxide, and 25 for methane), and the total CO_2e emissions are then expressed in tons throughout the report.

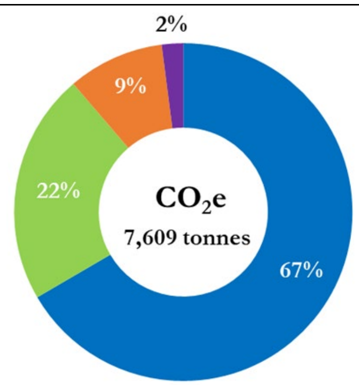
5.1 Current Emissions and Impact on Local Community

5.1.1 Port of Cleveland Baseline Air Emissions Inventory

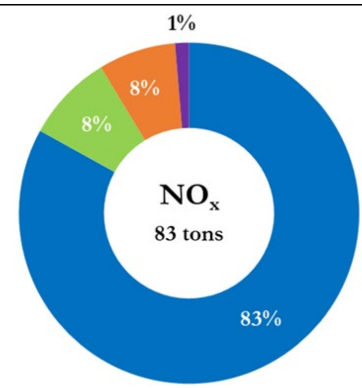
The Port Baseline Air Emissions Inventory study provides an overview of emissions associated with Port activities at the GCT, the cement facility, and the Cleveland Bulk Terminal. The total on-terminal emissions from 2022 are summarized on Figure 5-1. It is important to note that these emissions represent on-terminal activities only. The emissions from ocean-going vessels include only those generated during berthing, while transit and maneuvering emissions are excluded. Cargo handling equipment emissions occur solely on the terminal premises. For harbor craft, emissions from the assist and escort tugs directly involved with vessels calling the Port are accounted for. The on-road heavy-duty truck emissions pertain exclusively to on-terminal operations and do not encompass emissions outside the port terminals, such as those produced while driving on public roads.

Figure 5-1. Emissions Distribution by Mobile Source Category for Each Pollutant

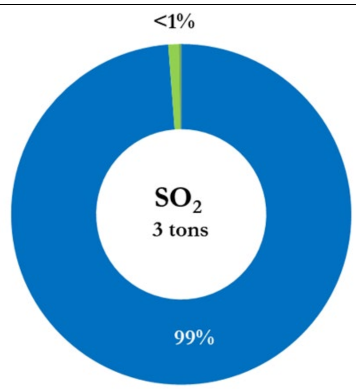
Source: Port of Cleveland 2022 EI Report (Cleveland-Cuyahoga County Port Authority 2023)



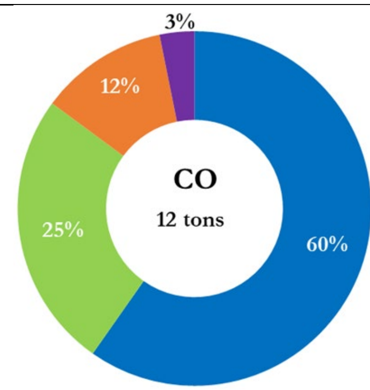
CO_2e Emissions Distribution (Displayed in Metric Tons) by Mobile Source Category



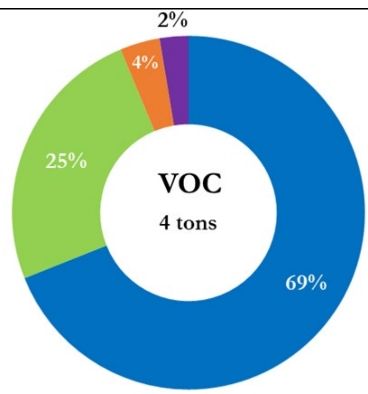
NO_x Emissions Distribution



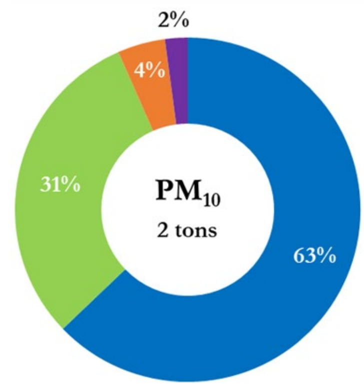
SO_2 Emissions Distribution by Mobile Source Category



CO Emissions Distribution



VOC Emissions Distribution



PM_{10} Emissions Distribution

■ Ocean-going vessels ■ Cargo handling equipment ■ Harbor craft ■ Trucks and Rail

5.2 Impact of Emissions on Local Community

Quantifying port emissions is crucial because they directly impact the surrounding community. Understanding the global maritime shipping industry's overall impact is essential, and it becomes apparent that maritime shipping significantly contributes to pollution levels, accounting for about 15 percent of global nitrogen oxides (NO_x) emissions, 5 to 8 percent of sulfur oxide emissions, and 2 to 4 percent of CO_2 emissions. Sources of these emissions include ship operations, port equipment, and onshore support activities, all of which lead to environmental and health consequences for nearby residents. Ultimately, emissions from ports can have a profound effect on the health of the local community. The environmental effects encompass air pollution, light pollution, water pollution, and noise pollution.

Of particular concern is air pollution resulting from port emissions, as it contributes to the formation of smog and haze, thereby reducing air quality in the area. Such deteriorated air quality can significantly impact human health, particularly for individuals with respiratory conditions like asthma. In addition, these emissions are linked to respiratory problems, cardiovascular diseases, and an increased risk of cancer among the exposed population.

In summary, the impact of port emissions on the local community's health is a pressing issue that warrants thorough understanding and concerted efforts to mitigate the adverse effects on residents' well-being.

Therefore, implementing port fleet electrification is a forward-thinking approach that holds the potential to create a cleaner, healthier, and more sustainable future for both the port operations and the communities they serve. By investing in greener technologies, port operators can take significant strides toward protecting public health and fostering a cleaner, more resilient world for generations to come.

5.3 Calculating CO_2 Equivalent Emissions for the Port of Cleveland's Internal Vehicle Fleet

Next, the emissions from each vehicle in the Port's internal fleet were converted to their CO_2e. In other words, each vehicle's annual diesel fuel use (in gallons) was converted to display the equivalence of CO_2 emissions per vehicle and vehicle type.

5.4 Emissions Breakdown and CO_2 Inventory of the Internal Vehicle Fleet

Table 5-2 shows the annual diesel or gasoline consumed for different vehicle categories along with their CO_2e in tons. These values were developed using the methodologies for determining vehicle energy consumption outlined in Section 7 and Appendix C. The methodologies outlined in Appendix C use a mix of U.S. Environmental Protection Agency (EPA) guidance, California Air Resource Board guidance, and actual empirical fuel data taken from the cargo handling equipment at Port of Cleveland.

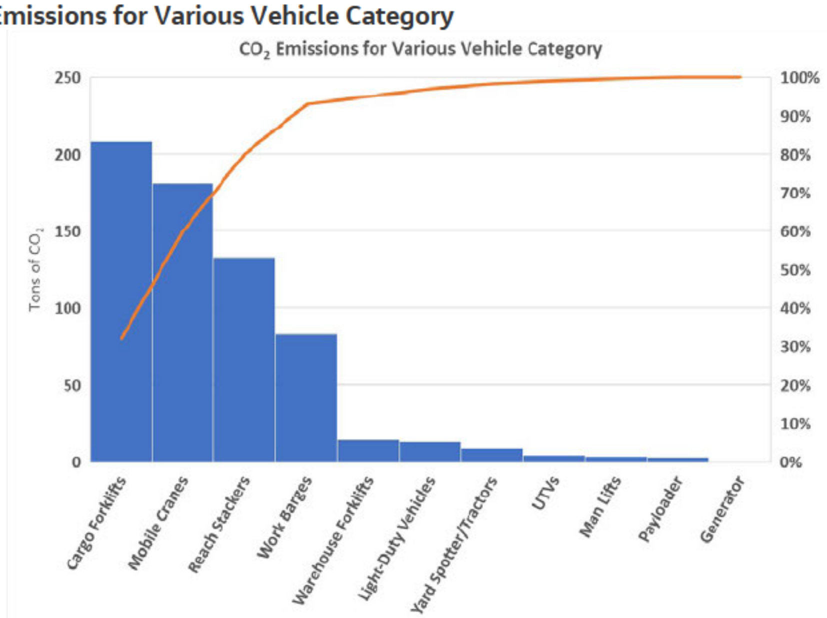
Figure 5-2 shows CO_2 emissions of different vehicle categories with a cumulative line on the secondary axis as a percentage of the total emissions for the existing fleet.

Table 5-2. Fuel Consumption and CO_2 Inventory of the Current Internal Vehicle Fleet

Vehicle Category	Gallons of Diesel/Gasoline Consumed	CO_2 Emissions in Tons
Cargo Forklifts	18,510	208.00
Warehouse Forklifts	1,249	14.00
Manlifts	308	3.50

Vehicle Category	Gallons of Diesel/Gasoline Consumed	CO_2 Emissions in Tons
Mobile Cranes	16,147	181.30
Payloader	259	2.90
Reach Stackers	11,818	132.70
UTVs	384	4.30
Work Barges	7,381	82.80
Yard Spotter/Tractors	783	8.80
Generator	20	638.50
Light-Duty Vehicles	1,342	13.20
Total Fleet	58,200	651.70

Figure 5-2. CO_2 Emissions for Various Vehicle Category



As shown on Figure 5-2, the cargo forklifts contribute to about 32 percent of the fleet's total emissions, which is significant considering that they make up 18 out of the 41 vehicles in the fleet. The mobile cranes, although only 2 in total, account for the second-highest percentage of emissions at approximately 28 percent.

Please note that this analysis is based on specific assumptions. The calculation of CO_2e emissions (in tons) considers only the direct tailpipe emissions resulting from the annual diesel fuel use (in gallons) of each vehicle. It does not account for the emissions generated during the production of diesel fuel itself.

This analysis was then taken a step further to display the emissions reductions the Port would see as EVs and their respective charging are phased in. This analysis is shown in Table 5-3.

5.5 EV Procurement Plan for the Ground Fleet

The state of Ohio demonstrates a commendable commitment to sustainability, with 17.2 percent of its electricity deriving from clean sources, including wind, solar, hydro, and nuclear energy (DOE n.d.). [redacted] Section 5.7 discusses the emissions inventory from the electricity mix at the Port.

Table 5-3. Emissions Reductions Associated with Vehicle Replacement Schedule

Vehicle	Short Term (0-2 years)	Short-Mid Term (2-5 years)	Mid-Long Term (5-12 years)	Long Term (10+ years)
Cargo Forklifts	10	7	1	0
Warehouse Forklifts	0	3	0	0
Payloader	0	0	1	0
Yard Spotter/Tractors	3	0	0	0
Mobile Cranes	0	0	0	2
Portable Generator	0	0	0	1
Reach Stackers	0	2	0	0
UTVs/Manlifts	2	1	0	1
Barges	0	0	2	0
Light-Duty Vehicles	1	3	1	0
Total Vehicles Converted	**16**	**16**	**5**	**4**
Emission Reductions Accounting for EV Charging (CO_2e)	34.8 tons	81.4 tons	26.4 tons	54.2 tons

As shown in Table 5-3, the emissions reductions compile after each replacement schedule. This means that there will be 16 EVs converted in the first phase, 32 EVs in the second phase, 37 in the third phase, and all EVs in the internal fleet by the final phase. The net possible emissions reduction over the next decade would be approximately 197 tons of CO_2e as new technologies are phased in for electrification. This total accounts for charging the EV equivalents of each vehicle in the fleet as they are phased in. The assumption was that the EVs are powered by electricity, measured in kilowatt-hours. After accounting for EV charging, the cumulative emissions reduced at the Port is graphically represented on Figure 5-3 and

Figure 5-4. To become fully net zero, the Port would need to seek green electrical grid options for future emissions reductions in the long term.

By transitioning the current fleet to ZEVs, the Port can make a significant long-term reduction of around 200 tons of CO_2e over a period of 10 years or more. Figure 5-3 illustrates how emissions reduce cumulatively during the EV procurement timeline.

On the other hand,

Figure 5-4 shows the remaining overall residual CO_2e after the transition to a ZE fleet. Even with a complete transition to ZEVs, there will still be around 418 tons of CO_2 emissions left over in the long term, spanning the 10+ years of EV procurement. These residual emissions result from the indirect emissions associated with electricity generation required to charge these EVs. Consequently, there is an urgent requirement for the Port to clean up its electricity grid in order to achieve net zero emissions in its operations.

Figure 5-3. Cumulative Emissions Reductions: Cumulative Emissions Reduced over EV Procurement Timeline

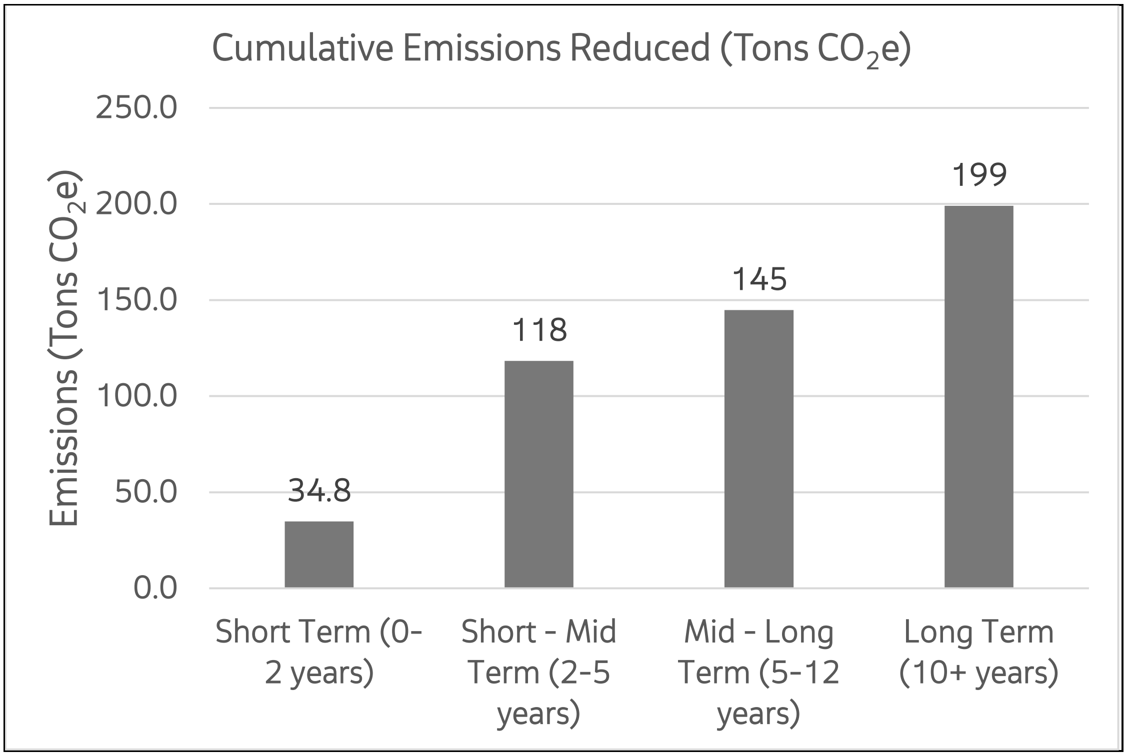
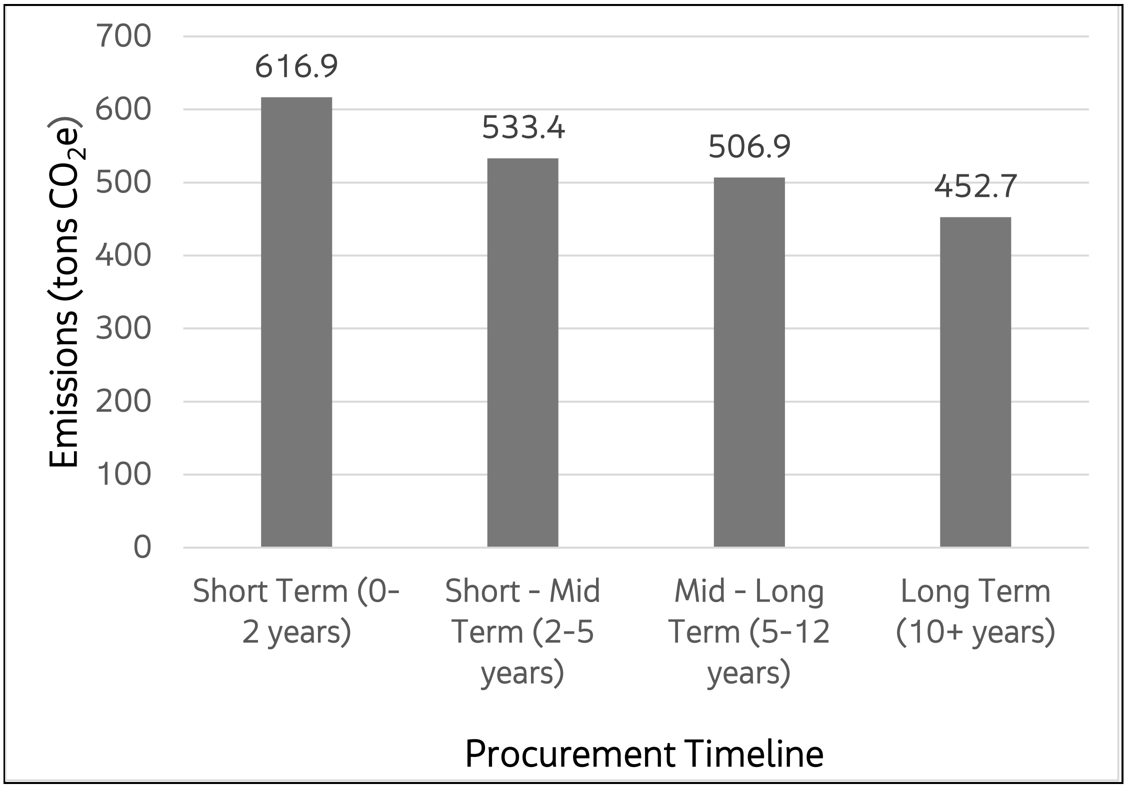


Figure 5-4. Cumulative Emissions Reductions: Overall CO_2e over EV Procurement Timeline



5.6 Emissions Breakdown and CO_2 Inventory of Port of Cleveland's Vessel Call

Next, the emissions from each vessel in the Port's internal fleet were converted to their CO_2 equivalent. To do this, the electrical demand, monthly over the course of 2022 (in kWh) was converted to display the equivalence of CO_2 emissions. This analysis uses the same assumptions as defined in Section 6.2.

Table 5-4 shows the monthly breakdown from 2022 of the energy consumed by vessel calls along with their CO_2e in tons.

Table 5-4. Energy Demand and CO_2 Inventory of Vessel Calls

Month	Vessels Energy Demand (kWh)	CO_2e Emissions (tons)
January	30,940	13.9
March	2,777	1.2
April	155,932	70.1
May	236,126	106.4
June	185,888	83.5
July	229,189	102.7
August	343,671	154.5
September	264,504	118.7
October	330,698	148.8
November	200,392	90.1
December	234,390	105.5
Totals	**2,214,506**	**995.4**

5.7 Emissions Inventory from Electricity Mix at Port of Cleveland

In addition to sources of on-port emission activities, the electricity mix of a port also plays a crucial role in determining its overall emissions profile. In other words, ports that rely on fossil fuel–based electricity generation contribute to GHG emissions and air pollution.

The electricity for the Port of Cleveland is sourced from CPP, the city's municipal electric utility. [redacted]

[redacted]

[redacted]

[redacted]

	[redacted]		[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]		[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]		[redacted]
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[redacted]	[redacted]	[redacted]		[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[redacted]

Table 5-5 and the accompanying Figure 5-6 provide a comprehensive overview of the environmental impact of our energy procurement strategies, with a specific focus on CPP. In, we detail the CO_2 emissions resulting from CPP's non-renewable power purchases, shedding light on the carbon footprint associated with their conventional energy sources. On the other hand, the Figure 5-6 visually illustrates the contrast between these emissions and the CO_2 savings achieved through CPP's investments in renewable energy sources. This comparison highlights the tangible benefits of CPP's commitment to sustainability, as it showcases the substantial reduction in CO_2 emissions that result from shifting towards greener energy alternatives. Together, these insights underscore the importance of CPP's efforts and our collaboration with them to minimize our environmental impact and contribute to a more sustainable future.

The Greenhouse Gas Equivalencies Calculator uses the AVoided Emissions and geneRation Tool (AVERT) was employed to convert kilowatt-hour reductions into avoided carbon dioxide emissions, specifically for assessing the impact of renewable energy programs. The eGRID tool played a key role in converting kilowatt-hour measurements into estimates of carbon dioxide emissions.

The analysis to quantify electricity mix was taken a step further to be more applicable to the Port itself, rather than its greater subregion. Therefore, the emissions associated with the Port’s annual electricity use were calculated. To do this, the annual electricity consumption was taken from the Port’s meter readings to calculate emissions related to the Port’s current annual electricity usage. For the year 2022, the monthly usage (reported in kilowatt-hours) at each of the Port’s 11 meters readings was totaled to calculate an annual electricity usage at each meter location. The usage at each location was combined to calculate an annual electricity consumption in kilowatt-hours for the Port. Annual electricity usage was then converted to the equivalent amount of CO_2 emissions, which is reported in Table 5-6.

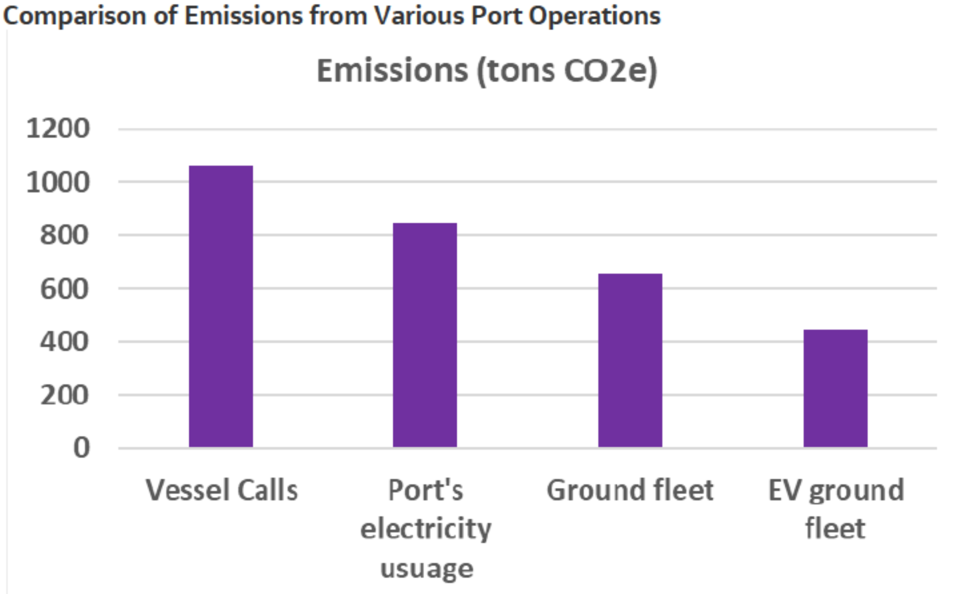
Table 5-6. Annual CO_2e of the Port of Cleveland's Current Electricity Use

Annual Electricity Usage at the Port	CO_2 Equivalent
1,775,245 kWh	847 Tons

The EPA's Greenhouse Gas Equivalencies Calculator translates abstract measurements of CO_2e into concrete terms that are easier to understand. For instance, the 847 tons of CO_2 produced at the Port is equivalent to CO_2 emissions from 860,234 pounds of coal burned, 86,414 gallons of gasoline consumed, and 149 homes' electricity use for 1 year. It is also equivalent to the GHG emissions from 171 gasoline-powered passenger vehicles driven for 1 year (EPA 2023b). This helps to put the Port's annual electricity use into perspective.

5.8 Summary of Emissions from Various Port Operations

Figure 5-7. Comparison of Emissions from Various Port Operations



As shown on Figure 5-7, the Port's emissions, measured in tons of CO_2e, come from various sources. Vessel calls contribute 1,057 tons, while the Port's electricity usage accounts for 847 tons annually. The emissions from the ground fleet amount to 653 tons, but the adoption of EVs for the ground fleet would reduce emissions to 445 tons. Even with a complete transition to ZEVs, there will still be CO_2 emissions left over.

Indirect emissions from the Port's electricity grid will be significant despite electrification. The remaining emissions stem from the indirect impact of generating the electricity needed to charge the EVs. This highlights the urgent need for the Port to transition to a cleaner electricity grid to attain net zero emissions in its operations. Acting in this area is crucial to enhance the Port's environmental sustainability efforts. To address the residual emissions and achieve net zero operations, the Port should consider implementing onsite solar roofing.

5.9 Cleaning the Electricity Grid: A Prerequisite for Net Zero Emissions

Achieving net zero emissions will be fully realized when the electricity used to charge the EVs and shore power for the vessels is sourced entirely from renewable energy. Although the transition to EVs and shore power represents a significant step toward reducing emissions, ensuring that the electricity used for charging comes from clean and renewable sources like solar is essential. By adopting renewable energy for EV charging and shore power, the Port can further decrease its carbon footprint and make substantial progress toward becoming a truly sustainable and environmentally responsible operation. Embracing green electrical grid options and investing in renewable energy infrastructure will be crucial in attaining the goal of net zero emissions in the long term. This commitment to renewable power generation aligns with the broader efforts to combat climate change and pave the way for a more sustainable future for the Port and the community it serves.

5.10 Achieving Port's Net Zero Emission Goal through Renewables

To address the residual emissions and achieve net zero operations, the Port should focus on implementing solar roofing as a more practical solution. A detailed discussion on this topic can be found in Section 9. Solar roofing offers numerous advantages, including feasibility for the Port's infrastructure and space availability for installation. By embracing solar roofing technology, the Port can significantly reduce its reliance on traditional fossil fuel–based electricity sources and move toward a cleaner, more sustainable energy future. Refer to Section 9 for a comprehensive analysis of the benefits and practicality of solar roofing for the Port.

The implementation of solar PV, paired with net metered energy transfer back to the CPP grid will not lead to 100 percent ZE operations because the CPP grid power has indirect emissions associated with the energy generation types in the Ohio region, although it will offset a majority of the power demand. To completely transition to a net zero emission operation, taking into account indirect grid emissions, it is recommended that the Port Authority explore renewable energy certificates to offset the remaining power from the grid, through a power purchase agreement (PPA). CPP has expressed openness to enter into PPAs with the Port directly in order to increase the percentage of clean energy utilized for the Port's operations. This partnership provides a great opportunity for the Port to realize its goal of net zero emission operations.

6. Energy Usage and Rate Analysis

6.1 GCT Fleet and Cargo Cold Ironing Power Needs

The combined power requirements for fully implementing an all–battery electric equipment fleet, and cold ironing for cargo ships, are outlined in Sections 7 and 8. The cruise ship terminal power needs are separate from the GCT cargo and fleet power calculations and are addressed in Section 6.4.

6.1.1 Cargo Cold Ironing

- Assumed scenario: Two HandyMax sized cargo vessel and three Liebherr LHM280-3 mobile harbor cranes with electric-drive retrofits
- Cargo Cold Ironing Average and Max: 740 kW
- Mobile Harbor Crane Average: 600-900 kW
- Mobile Harbor Crane Max: 2 MW

It is important to note and explain the characteristics that contribute to the maximum load of 2.75 MW and why it is anticipated that this load would be substantially lower in the long term. This number includes the assumed maximum load of 670 kW per mobile harbor crane. This is the maximum power rating of the electric-drive system as provided by Liebherr. No operational load factor was applied in Section 6 when determining the total power needs, and it should be noted that the proposed retrofit assumes the installation of two 220-kW drive motors. It should be assumed that the actual nominal average kilowatts of the mobile harbor cranes would fall closer to 200 to 300 kW. The 370 kW per HandyMax cargo vessel is assumed to be both the average and maximum requirements.

The mobile harbor cranes are expected to be operated only during the day's normal working hours from 7 a.m. to 4 p.m., Monday through Friday, during the summer and fall operational shipping months. The cold ironing loads from the cargo vessels are anticipated to be 24 hours a day and potentially up to 7 days a week depending on the ship's schedules and layover timing.

6.1.2 Battery Electric Cargo Handling Equipment Charging

- Total Average 1.18 MW
- Max 1.73 MW

Using the vehicle analysis from Section 6, we identified the average nominal power load based on daily energy usage of the current diesel-powered fleet. We also selected a readily available EV charger on the market, pairing the available EV charger's inverter module sizing and connector type to each vehicle. This produces a maximum possible power load, based on the charger's full load amperage and nameplate maximum rating. Table 6-1and Table 6-2 show the power load levels for the average nominal load as well as the maximum nameplate load, broken down by building and equipment asset types.

Table 6-1. Power Loads by Building

Building	Charger Power Level Based on Operations (Nominal Load) (kW)	Recommended Charger Power Level (Max Load) (kW)
Warehouse A	1,057	1,444
Warehouse 26	44	134.4
Offsite Dock—to support Flotsam and Jetsam support boats	86	150
	1,187	1,728.4

Table 6-2. Power Loads by Asset Type

Asset Type	Charger Power Level Based on Operations (Nominal Load) (kW)	Recommended Charger Power Level (Max Load) (kW)
Forklift	376	600
Reach Stacker	132	240
Generator	5	7
Manlift	22	20
Sweeper		7
Yard Spotter/Yard Tractor	182	180
Payloader	100	30
Switching Locomotive	240	360
Pickup	15	57.6
SUV	10	38.4
UTV	19	38.4
Work Barge	86	150
	1,187	1,728.4

It is anticipated that a fully electric vehicle, equipment, and boat fleet at the Port would have a total average power load of 1.18 MW, with a maximum connected nameplate load of 1.73 MW. It is important to note that that total power is split between three locations: Warehouse A, Warehouse 26, and an offsite dock location for the work barges.

The transition to all-electric is recommended to be through a phased procurement and replacement schedule, replacing current diesel vehicles at their end-of-life with electric equivalents, as outlined in Section 4.4. This phased vehicle replacement approach has the additional benefit of enabling the additional power to the Port from CPP to be implemented in phases. Figure 6-1 illustrates the necessary power requirements to provide charging for new battery electric vehicles as they are procured and deployed at the Port.

Figure 6-1 illustrates the maximum power (in kilowatts) needed by the port to sustain charging for the fleet over the next 10+ years.

Figure 6-1. Nominal and Maximum Power Load Growth over Time for Cargo Handling Equipment Charging

In addition to the peak power required to serve the fleet, we also calculated the estimated daily and annual energy required to charge the varying fleet of battery electric equipment and vehicles. The fleet's energy requirements in kilowatt-hours are summarized in Table 6-3and further expanded in Table C3 in

Appendix C. To estimate the yearly energy demand, we applied the 2022 equipment annual operating hours to the modeled maximum daily energy requirements. In applying the 2022 operating hours for the equipment, we estimate actual annual energy usage of 9,820 megawatt-hours (MWh), or 0.98 gigawatt-hour (GWh). Additionally, is estimated that daily the fleet will consume approximately 3.8 MWh in an average day-shift scenario. This was calculated by dividing the yearly energy demand in kilowatt-hours by the anticipated 250 working days.

Table 6-3. Energy Demand (in kilowatt-hours) of the Battery Electric Cargo Handling Equipment Fleet

Type	Yearly Energy Demands (kWh)	Average Daily Energy Demand (kWh)
Forklifts	319,806	1,279
Generator	326	1
Manlift	4,984	20
Mobile Crane	261,347	1,045
Payloader	4,190	17
Pickup Truck	10,059	40
Reach Stacker	191,269	765
SUV	6,351	25
Switching Locomotive	45,413	182
UTV	6,209	25
Work Barge	119,468	478
Yard Tractor	12,667	51
	982,089	3,928

Time of day charging and energy usage, paired with CPP utility rate tariffs and demand charges, should be further factored into the final strategy for energy. This is discussed in further detail in Section 6.5.

6.1.3 Usage Assumptions

All equipment and vehicles, including the rail locomotive, are included in this total power requirement. As noted in Section 6.1.2, the average power of 1.18 MW is determined by the actual daily vehicle/equipment energy consumption, while the maximum is the summed values of the maximum charger equipment power ratings. All cargo equipment, vehicles, and support equipment that compose the larger GCT fleet are anticipated to recharge each night during off-shift hours from approximately 4 p.m. to 7 a.m. the next day.

With the power requirements for the battery electric fleet occurring off-shift, and the power needs of the mobile harbor cranes occurring during the daytime work shift only, it should be assumed that these loads would not be occurring at the same time, allowing the Port to efficiently use the spare capacity from CPP over a 24-hour period. Site-level load balancing software and systems should be implemented to ensure that the EVSE are able to ramp up and down based on the mobile harbor crane loads so as to not exceed the site's capacity from CPP. Assuming this load balancing element, the average load required from CPP would be that of a night-time off-shift scenario with both the cargo ship cold ironing of two HandyMax-sized vessels and the charging for the vehicle and equipment fleet. This would equate to an average load of 1.92 MW and a maximum load of 2.47 MW. Note that this would occur only during the Port's seasons operating months of April to December. During the winter months, the crane and cargo loads would not be present.

[redacted]

The previously calculated power needs show that with the available CPP capacity, it is feasible to implement cargo cold ironing, hybrid electric mobile harbor cranes, and a battery electric GCT fleet long term without the needs to upgrade the existing 12-kV or 138-kV electrical infrastructure upstream. Further investigation is required with CPP to ensure the seasonality and impacts of other facilities, such as the stadium, and how it would impact available capacity.

6.2 Integration of Onsite Power Generation and Renewables

Also contributing to the overall feasibility is the addition of the 4.8-MW solar array atop Warehouse A, 24, and 26, detailed in Section 9.

During the peak sunny months, which closely align with the operational shipping season of the Port from April to December, this configuration would allow the daytime cargo cold ironing and mobile harbor crane operations to be potentially powered completely by the solar on the three warehouses reducing the need from CPP substantially. In Section 9, the daily average energy production during the working day shift (7 a.m. to 4 p.m.) is shown as a maximum of 13 MWh in July with flush-mounted solar systems. With an average daytime 8-working hour shift of three mobile harbor cranes and two HandyMax cargo ships equating to approximately 13.12 MWh, during the peak summer months the solar has the potential to offset up to 98 percent of the Port's total daily crane and vessel operational load.

Developing onsite power generation via solar have tangible benefits over and above reducing emission by providing cleaner energy than the local Ohio grid, in the form of providing an energy capacity buffer to the grid. From the data gathered in Section 9, it can be concluded that combining the energy produced -by Warehouse A, Warehouse 24, and Warehouse 26 solar PV array would equate to an annual energy production of 4.8 GWh. In contrast, the total annual power consumption for cargo cold ironing, mobile harbor cranes, and the entire GCT fleet equates to 2.64 GWh. This leaves an estimated annual power excess of 2.161 GWh more provided to the grid than is consumed. This annual excess would then be used to offset and power 120 percent of Port's larger facility electrical loads, which are estimated to be 1,775,245 kWh, or 1.78 GWh annually.

These numbers are averaged annually, so the day-to-day power draw will need to be closely monitored via site-level load balancing and peak shaving software and systems. During the months of February, March, April, and June, the Port will produce more energy than it consumes, providing a significant greening impact for the downtown Cleveland CPP grid.

Table 6-4 and Figure 6-2 illustrate further the percentage offset that renewables have on the month-over-month and annual usage. The power draw quantities shown are all inclusive, with both existing 2022 building power needs and the modeled cruise ship power needs. With all anticipated power needs, it can be expected annually that the overall usage of the Port on the CPP grid will be substantially less than the 2022 electrical usage.

Table 6-4. Summary of Port Facility Electrical Loads and Renewable Energy Offset

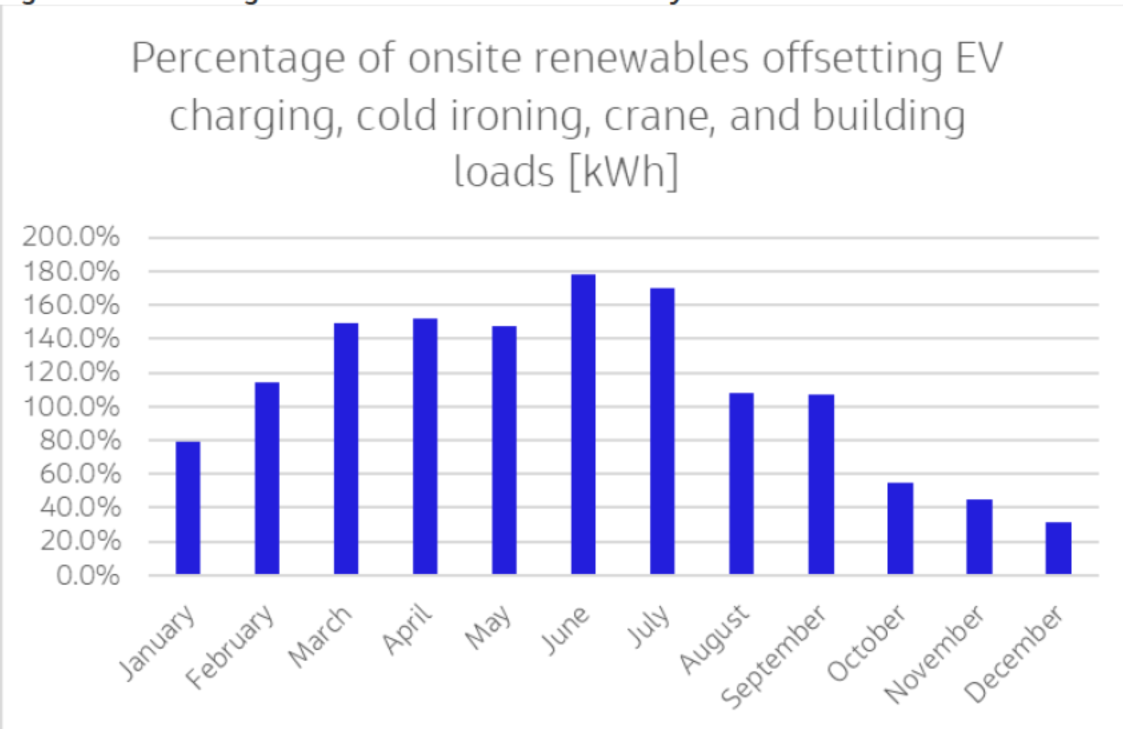
Monthly kWh							
Month	Percentage of Onsite Renewables offsetting Daily Fleet and Cold Ironing Loads (kWh)	Solar Generation (kWh)[a]	GCT Fleet Charging and Crane Load (kWh)[b]	Cruise and Cargo Ship Cold Ironing Load (kWh)[c]	Current Building Loads for All Buildings within the Port (kWh)	Total Monthly Loads (kWh)	Delta from Total Generation to Total Loads (MWh)
January	78.8	190000.0	76688.6		164432.3	241120.9	-51120.9
February	114.6	230000.0	76688.6		124092.4	200781.0	29219.0
March	148.9	350000.0	76688.6		158437.5	235126.1	114873.9
April	152.1	500000.0	76688.6	150,000.0	101966.6	328655.2	171344.8
May	147.3	625000.0	76688.6	225,000.0	122,706.8	424395.4	200604.6
June	177.8	650000.0	76688.6	150,500.0	138,409.0	365597.6	284402.4
July	169.7	665000.0	76688.6	180,000.0	135,272.8	391961.4	273038.6
August	107.9	550000.0	76688.6	275,000.0	157,850.2	509538.8	40461.2
September	106.7	450000.0	76688.6	200,000.0	145,233.2	421921.8	28078.2
October	54.8	280000.0	76688.6	260,000.0	173,880.0	510568.6	-230568.6
November	45.2	175000.0	76688.6	140,000.0	170,900.9	387589.5	-212589.5
December	31.3	125000.0	76688.6	140,000.0	182,063.1	398751.7	-273751.7
SUM		4790000.0	920263.0	1720500.0	1775244.8	4416007.8	373992.2

[a] Monthly solar generation based on flush-mount solar PV array on Warehouse A, 24, and 26. Multiplying daily average times 30 days in a month.

[b] Monthly GCT fleet charging load was developed in Section 7, by taking the yearly energy needs and dividing by 250 working days. Inclusive of anticipated mobile crane energy needs from 2022 fueling data.

[c] Monthly cold ironing from Section 6, "Cold Ironing Energy per Month."

Figure 6-2. Percentage of Loads Ran from Renewables by Month



6.3 Stationary Battery Storage

Stationary battery energy storage systems can shift excess solar power during periods of cloud cover or at night to offset retail grid power. Although it is currently unknown how CPP would treat excess solar energy or net metering, a review of the current electric tariff and projected load profile suggests that a stationary storage system would be deployed to exploit any difference between retail rates and a solar sellback rate (“energy arbitrage”). A sellback rate would be set by CPP, and early discussions indicate that it would be less than the full retail rate. To provide the Port an example of how the battery storage might operate, consider a sellback rate of $0.02/kWh and $0.04/kWh, while storage could offset an assumed conservative retail rate of $0.12/kWh that captures the Energy Adjustment Charge (EAC). In addition, the analysis considers 4-hour Tesla Megapacks ranging from 3.9 MWh to 27.4 MWh. Payback period results for adding storage systems are summarized in Table 6-5.

Table 6-5. Storage System Payback Periods

Unit	Cost	Annual Fee	Simple Payback Period
1 Megapack—4 hours	$2,014,680	$8,440	15+ years
2 Megapacks—4 hours	$3,618,220	$13,400	25+ years
3 Megapacks—4 hours	$5,385,450	$18,370	25+ years
4 Megapacks—4 hours	$7,134,460	$23,330	25+ years
5 Megapacks—4 hours	$8,865,240	$28,290	25+ years
6 Megapacks—4 hours	$9,941,250	$33,260	25+ years
7 Megapacks—4 hours	$11,529,870	$38,220	25+ years

Note:

Costs, including capital and annual, are obtained from https://www.tesla.com/megapack/design for the delivery date Q4 2025.

6.4 Cruise Terminal Cold Ironing Power Needs

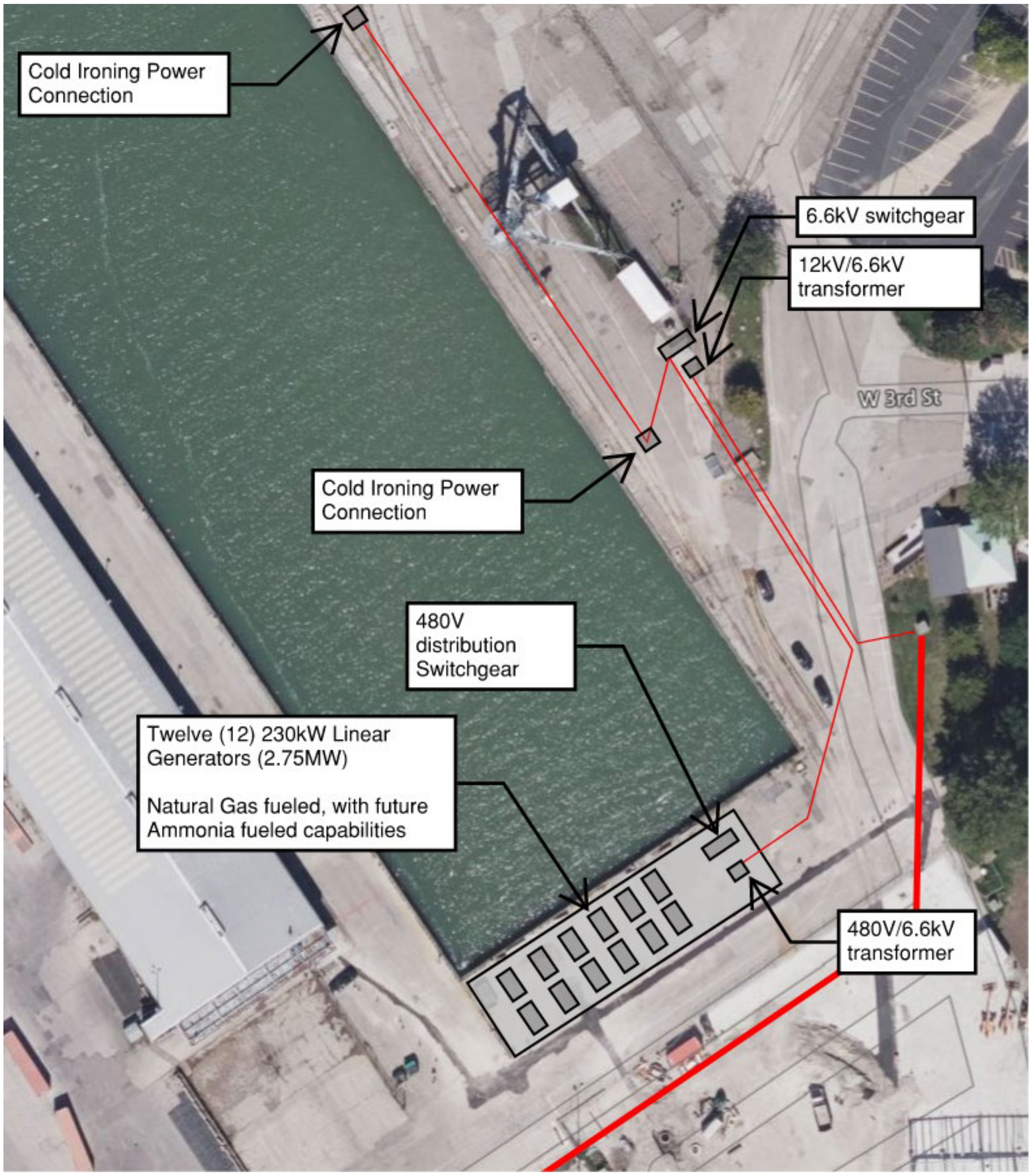
Although the cargo vessels are currently not capable of cold ironing in the short term, the large, newer cruise ships that call to the Port, specifically the Viking Polaris, do have the ability to cold iron today (Section 6.1). As summarized in the cold ironing analysis, the electrification of the cruise terminal presents a real and tangible option to reduce emissions for the Port in the short term.

Unfortunately, the power loading and the characteristics of the power delivery to the cruise ships presents an issue from a power infrastructure feasibility standpoint. It is anticipated that a large cruise ship the size of the Viking Polaris will require up to 2.45 MW, which constitutes a large percentage of overall power needs for the electrification of the Port. This load alone also exceeds the available current CPP capacity [redacted] The power needs of the larger cruise ships that call to the Port are also characterized as sporadic and occasional peak loads over the seasonal summer operating window, which is not ideal in terms of a balanced and consistent annual load from the CPP grid. It is recommended that the power needs of the cruise terminal and dock be treated as a separate project from the cargo docks, cranes, and GCT fleet electrification.

To implement cold ironing for the cruise terminal, multiple scenarios are envisioned:

1. Scenario #1: Develop a behind-the-meter onsite power generation strategy that can provide occasional "peak" power to the cruise ship terminal on demand and without additional CPP grid capacity upgrades and separate from the infrastructure being built at Warehouse A (Figure 6-3). This could be developed independent of adjacent City of Cleveland lakefront developments and initiated in the short term. Usage of natural gas–powered linear generators would provide significant emission reductions, while also providing the necessary power for cruise ships. This solution could also supplement the cargo ship cold ironing and battery electric equipment charging when a cruise ship is not present, provide peak shaving functions, and provide resiliency during grid outages.

Figure 6-3. Concept Layout of Proposed Infrastructure Upgrades to Power the Future Cruise Terminal with 100 Percent Behind-the-Meter Onsite Generation



2. Scenario #2: Develop a strategy with CPP to bring a new dedicated 12-kV circuit, separate from the Warehouse A infrastructure upgrades, to serve the cruise terminal cold ironing infrastructure. This will need to align with the larger energy strategy connected to the development of the adjacent City of Cleveland North Coast Master Plan development project, requiring more time to develop.

6.5 CPP Rate Analysis

An analysis of CPP's rate structure provides some insights on best scenarios of the Port as they upgrade the electrical service capacity of Warehouse A, in addition to developing a large solar PV generation interconnection with the CPP downtown grid.

Warehouse A's electrical feed and meter from CPP is currently billed at "Large Commercial" rate schedule with monthly loads ranging from 17 MWH to 100 MWH. CPP does not currently offer a "standby" or explicit net metering tariff, though many other utilities such as FirstEnergy (Illuminating Company) offer specific rates for standby (e.g., if a facility has its own generation) or net metering with solar.

Potential CPP rate discounts that the Port could take advantage of are:

- Discount of 2 percent for primary metering (>2,300 V)
- Discount if facility owns the transformer and substation
- Combined billing is possible and may provide ability to combine all accounts under a more favorable Large Commercial Rate

The Industrial and Large Commercial Tariffs, as published, are nearly identical and differences may be present in the EAC, which is the majority of the bill costs. Jacobs recommends a conversation with CPP to estimate differences on the EAC between the tariffs. Consolidated billing is possible under all rates; suggest that the Port consolidate billing to have the most favorable overall rate.

In addition, it should be assumed that when net metering solar power back to the grid the anticipated revenue should be an assumed general wholesale rate of 5 cents per kilowatt-hour and not inclusive of the EAC. During conversations with CPP, it was noted that the EAC charges could be negotiated and reduced, depending on the amount of onsite renewables and net-metered power that the Port of Cleveland generates. Future engagement and conversation is required to negotiate and develop an agreed-upon net-metered rate structure for the Port's solar renewables.

7. Fleet Analysis and Replacement Recommendations

Today, the Port operates a fleet of 40 vehicles plus one mobile generator (which will be referred to as a vehicle in this report) with all currently being powered by fossil fuels. As these vehicles reach their end of life, the Port is committed to replacing them with ZE equivalents. As such, it is critical for the Port to understand when each vehicle needs to be replaced and what ZE equivalent on the market today can provide the necessary performance to prevent any negative impact to the Port's operations. In this section, a summary of findings is provided for each of the vehicle and equipment types on site at the Port. In addition to analyzing the existing fleet assets on a 1 to 1 basis, Jacobs also assumed future growth of the Port's operations and subsequent expansion of the fleet from what it is in 2023. The following growth assumptions were used in determining the final electrical needs of the Port:

- Increase the container cargo handling fleet from two pieces of equipment to four, adding two more container handlers in the next 10 years.
- Increase the mobile harbor crane quantity from two to three, adding one more mobile harbor crane in the next 10 years.
- Increase the yard tractor quantity from three to five, adding two more yard tractors in the next 10 years.

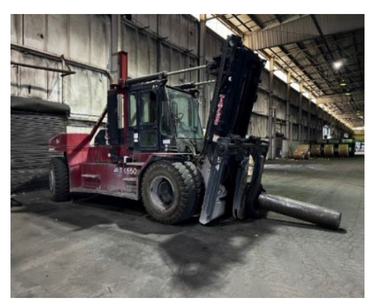
Understanding the energy requirements of each asset in the Port's future fleet is crucial as it will help inform the suitability and feasibility of ZE emission replacements for the existing internal combustion engine (ICE) assets. Additionally, understanding each assets energy demand will inform what charging infrastructure is necessary and what capacity is needed in the energy grid and what size battery or hydrogen fuel tank is needed to ensure the asset can meet service. To understand each asset's energy daily and annual energy demand, detailed fueling and utilization records needed; unfortunately, there is limited empirical data for most of the Port's assets. As such, a methodology was developed following industry best practices that estimates each asset's max daily and average annual energy demands, found in Appendix C. The energy demand analysis, asset classifications and a market analysis will be used to assess the level of difficulty for electrification for each asset and what ZE equivalent is best for the Port, shown in detail in Appendix D. Collectively these findings will inform the Port of the necessary infrastructure needed to support a fleet of ZEVs.

7.1 Zero-Emission Equivalent Analysis and Recommendations

7.1.1 Cargo Handling Equipment

The most critical vehicle types in Port's fleet are their mobile container and cargo handling equipment: forklifts and reach stackers. These vehicles represent 55 percent of the fleet but 73 percent of all the Port's equipment operating hours. in 2022, with the port operating them one shift per working day year-round, totaling about 250 working days per year. The mobile cargo handling equipment assists the mobile harbor cranes in unloading the cargo ships and then transferring the cargo to other modes of transportation, storage areas, or facilities. Because the Port handles specialty cargo types of various sizes and weights, some of the port's forklifts are fitted with specialty attachments like the coil ram, as shown on Figure 7-1, and have lifting capacities that range from 5,550 to 99,200 pounds.

Figure 7-1. Forklift with Coil Ram Attachment



While hydrogen fuel cell technology offers faster refueling time, and extending operating time compared to battery electric cargo handling equipment, the technology is less mature, fuel is limited and costly and the unit costs are higher. Given the Port has single shift operations, the main benefit of fast refueling and extend run time is not needed. As detailed in the following section, the existing battery electric reach stackers and heavy-duty forks lifts have sufficient energy storage to meet the max daily use case that Port could expect. As such, the preference for cargo handling equipment is battery electric.

7.1.2 Yard Tractors

Figure 7-2. Yard Tractor

The Port use their Yard Tractor to support the mobile harbor cranes and cargo handling equipment at the Port (Figure 7-2). These vehicles represent 7 percent of the fleet and less than 1 percent types of all the Port's equipment operating hrs. in 2022. The Yard Tractors currently at the Port terminal were observed to be only used on occasion to move miscellaneous heavy trailers around the Port GCT footprint. They are not used daily in typical port cargo handling and ship loading/unloading operations, nor are they used in the movements of off-terminal bound container trailers.

Upon initial review, given the use case of the Port, the current capabilities of battery electric yard tractors are more than adequate and could replace the current diesel variants with no impact on Port operations.

As container operations grow and the trucks are used in a more continuous daily operation to shift trailered container cargo across the GCT, then midday opportunity DC fast charging between 60-120 kW should be used. The BYD 8Y is capable of a maximum DC fast charging rate of 120 kW. Jacobs sees little to no risk in recommending a battery electric yard tractor to replace the current ICE powered variants and that there is no need to consider fuel cell yard tractors.

7.1.3 Mobile Harbor Cranes (Battery Electric)

The Port operates two Liebherr LHM280-3 mobile harbor cranes procured in 2015. These cranes used for the loading and unloading of both bulk cargo and containerized cargo. This crane type is generally rarer for ports within the U.S. and the Port is one of few ports in the Midwest that use these machines for daily cargo operations. The Port currently does not use any permanently mounted or rail mounted cranes.

When a break bulk vessel containing steel coil calls at the facility, up to two mobile harbor cranes will be used to unload the cargo from the vessel. Alternatively, some of the break bulk vessels are self-unloading, and the vessel's own onboard crane may be used in conjunction with one of the Port's mobile harbor cranes. While there are currently two mobile harbor cranes in use at the Port, Port operations foresees continued growth in cargo throughput and vessel berths resulting in the need for an additional mobile harbor crane bringing the total fleet size to three. Given the nature of crane activity, the vehicles available on the market skew heavily toward battery electric, and notably tethered electric variants.

It is recommended that the Port retrofit their existing Liebherr mobile harbor cranes with the addition of an electric drive and tethered cable connection drawing power from a cold ironing power location quayside. Given the mobile harbor cranes are grid tethered in their primary operating mode of loading/unloading cargo, and minimal time is spent untethered moving the cranes around the port, the cost of hydrogen fuel cell, and the inherent benefits of hydrogen fuel cell technology, provide little tangible benefit for this equipment type. As such, the preferred ZE technology type for mobile harbor cranes is battery electric.

7.1.4 Rail Locomotive

Figure 7-3. Rail Locomotive

Currently the port has one switcher locomotive (Figure 7-3). This is an EMD GP9, a 4-axle locomotive weighing around 260,000 pounds and with 1750 horsepower (hp), which dates from 1955. It is used to shunt strings of typically four or five cars between trains delivered to the port boundary and the ship loaders. The client has advised that the locomotive is not in operation every day and has relatively low duty cycle, operating for around 24 hours per month. The low demand on the locomotive therefore does not justify a large capital outlay for a new, higher performance locomotive.

Given an assumed max 8 hours of operation in a working day, along with the assumed average hourly fuel consumption, the max daily energy demand returned from the analysis was 6,055 kWh, well below the planned 1400 kWh for the retrofit. However, the Port project the switcher only operated 60 hours in 2022, or an average of 1.6 hours a week assuming 187 working days per year. As such, Omnitrax plan to convert the EMD 567 into a battery electric switcher with 1400 kWh of energy storage shall be more than sufficient. The diesel engine and generator will be removed and replaced with a 1.4-MWh nickel-manganese-cobalt battery, with nominal voltage of 750 V DC, and traction control system from Alternative Motive Power Systems (AMPS).

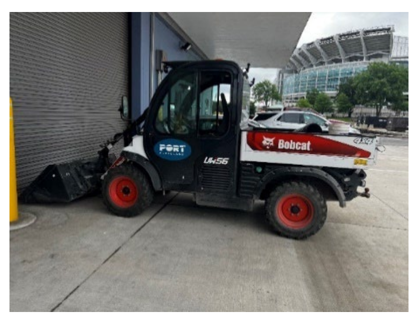
7.1.5 Light-Duty Car and Truck Support Vehicles

The Port uses a small fleet light-duty trucks and SUVs for maintenance and administration activities in and around the Port facility. The administration fleet consists of one class 1 light-duty pickup truck, a 2018 Chevrolet Colorado which is normally stored at the Port administration offices located at 1100 W. 9th. Administration uses their truck for travel locally and around the Port and occasionally use the vehicle to travel to conferences in the region.

Currently available battery electric equivalent to the Port's light-duty and pickup fleet has sufficient battery capacities to prevent any disruption to the Port's operations. Additionally, most of fleet have a lot of useful life remaining, so when the vehicles are due for replacement the Port will have additional battery electric options available to them.

7.1.6 Other Support Equipment Considerations

Figure 7-4. Utility Task Vehicle



The Port currently operates two UTVs onsite to support their facility and port operations groups (Figure 7-4). Both vehicles are fueled with diesel. These vehicles were observed as mostly being used for daily maintenance activities, in addition to occasional dirt moving and light snow clearing functions. Daily usage is sporadic and on an as-needed basis.

Continuous 8-hour operation of the UTVs, given their engine sizing and fuel consumption, resulted in an max daily energy demand of 161 kWh and 66 kWh, respectively. In Section 3, it was assumed that the UTVs operate 250 working days per year during normal working hours. In 2022 the UTVs collectively operated 485 hours, equating to an average daily runtime of 0.97 hour per day per vehicle. Given the small footprint of the Port, and the low annual and daily operating hours, it is anticipated that the current available battery electric commercial UTVs on the market will meet the needs of the Port in regard to energy.

7.1.6.1 Facility Sweeper

Figure 7-5. Facility Sweeper

The Port currently operates one 60 inch width sweeper machine within the GCT and its warehouses (Figure 7-5). The piece of equipment was not on the provided equipment list from the Port, but was observed as being operated onsite, parked within Warehouse A. The current vehicle is a Tennant 8410 with a 60-inch sweeping width, an 84 hp GM motor, and 33-pound liquid propane gas fuel tank. Daily usage is sporadic and on an as-needed basis.

In the United States, battery electric sweeper products are commercially available, though they are mostly focused to urban outdoor use cases, specifically for congested downtown areas and small paved pathways like bike paths. If and when the Port replaces the existing sweepers, the duty cycle can be further analyzed and an adequate EV equivalent can be identified.

7.1.6.2 Manlifts

Figure 7-6. Snorkel TB60

The Port currently operates two manlifts within the GCT and warehouses primarily for maintenance activities (Figure 7-6). The two manlifts are made by Snorkel and are classified as articulating boom lifts. Both use a diesel engine to power the hydraulic system which provides the force to the drive and lifting systems. Daily usage is sporadic and on an as-needed basis.

Manlifts have the ideal use case for electrification as they are typically operated indoors, have short operating cycles, and spend most of their operating hours static with the energy demand mostly being used to operate the boom and platform. As such, the manlift industry has quickly been trending battery electric with lead acid battery power manlifts being a staple in the industry for years. the maximum platform height on commercially available battery electric manlifts is 60 feet with manlifts over platform heights above this still only being offered in ICE variants. If the Port determines that a platform height of 60 feet is sufficient, they can elect to replace the TB80 with a battery electric manlift. Otherwise, the Port will have to wait until manufacturers adopt their lithium-ion battery technology to manlifts with higher platform height capabilities.

7.1.6.3 Mobile Power Generators

Figure 7-7. Kubota GL14000

The Port currently operates one towable generator within the GCT to provide mobile power for maintenance activities (Figure 7-7). The unit is a Kubota GL14000 which is has a rated output of 12 kW and can supply both single phase 120 V and 240 V. The generator uses diesel fuel and has Tier 4 emission controls. The Port's current generator was purchased in 2022, has the highest tier emission control systems, and minimal annual utilization. As such, their minimal benefits to immediately replacing with the recommended EV equivalent, but when the Port is ready numerous battery electric options will be available.

7.1.6.4 Pay Loader/Wheel Loader

The Port currently operates one wheel loader. This wheel loader operates within GCT and is primarily used for clearing snow in the winter. The wheel loader operated by the Port is a Volvo L180H.

Given that the payloader only had 28 operating hours in 2022 it is assumed that a full 8-hour operating day is not typical, and that realistically the equipment would only operate on average of 0.6 hour per week given an assumed 250 working days per year. As such, the recommended EV equivalent, LiuGong 856HE, which is currently available for purchase would have more than enough energy storage to serve the Port's operational needs. However, the 856HE and all other currently available battery electric wheel loaders have less lifting capacity than the L180H. Given the low use of the current wheel loader, it is expected the Port is not needing to immediately replace the asset. By the time the Port is ready to purchase a new wheel loader, more battery electric options will be available, and they can make the selection that best serves their needs.

Figure 7-8. Work Barge

7.1.6.5 Work Barges

The Port operates two 25-foot lake barges made by Lake Assault (Figure 7-8). The Port uses these barges to clean up trash and debris that make its way into the harbor. As such, the barges typically operate at trolling speed with one boat using a mini excavator and the other using a small crane arm to remove debris from the water.

After consulting Lake Assault, it is assumed the hulls of the current barges operated by the Port will have a useful lift of 30 years, resulting in an end of useful like in 2042. As such, battery electric propulsion retrofit kits were reviewed rather than new vessels for the recommended EV equivalent. Given the continuous 8 hours of operation of the work barges, and the assumed average hourly fuel consumption, resulted in a max daily energy demand of 519 kWh, well below the energy capacity of currently available battery electric propulsion retrofit kits. However, due to the low intensity duty cycle of these boats, it is believed this analysis methodology results are not representative of the actual max daily energy demands. As such, it is recommended further empirical analysis is conducted to determine the true max daily energy demands of these boats. If further analysis confirms the recommended battery electric propulsion retrofit kit has sufficient energy capacity to meet the needs of the Port, Lake Assault confirmed they have the resources to do both the design and installation of a Torqeedo system into the Port's work barges. Due to the work barges not being used in the winter, the retrofits could be scheduled during typical down time and be returned to the Port with no impact to operations.

7.2 Procurement Strategy and Timeline

A vehicle replacement analysis was conducted based on an assumed useful life criteria, shown in Appendix C. These criteria take into account various factors, including the age of the vehicles and their respective usage hours during the year 2022. By analyzing these variables, we were able to categorize the vehicles and identify the appropriate priorities for their phased replacement.

The initial step in the replacement analysis involved determining the age of each vehicle. This information was provided to us or collected during our survey, specifying the manufacturing dates of the vehicles. By considering this data, we were able to establish the current age of the vehicles accurately.

Simultaneously, we estimated the total asset usage for each vehicle. To accomplish this, we extrapolated the usage data for the year 2022 and projected it across the entire lifespan of each vehicle. It is important to note that these timeline estimates are "soonest available" and while it is recommended to begin the transition to ZEVs when possible, vehicle lead time and availability, as well as the readiness of the electrical and charging infrastructure as defined in the hub-and-spoke project phasing roadmap in Section 2.

Upon gathering the age and usage data, we proceeded to examine four distinct replacement scenarios to illustrate which vehicles and equipment should be prioritized for replacement, all starting in 2030 as part of the initiation of the Spoke C phase:

1. Short-Term Deployment (2030 to 2032)
2. Short-Mid-Term Deployment (2032 to 2035)
3. Mid-Long-Term Deployment (2035 to 2042)
4. Long-Term Deployment (2042+)

By analyzing how the age and usage of each vehicle progressed, we determined the appropriate replacement scenario for each vehicle. Table 7-1 provides an overview of the ratings assigned to each class. After considering the level of electrification difficulty for each vehicle, we initially decided to reclassify two boats from the short-term replacement category to the medium-long term category. This decision was influenced by the fact that electric vessels are currently a niche product in an emerging market with significant potential for rapid growth within the next 5 years. However, after further discussions with the Port and the hull and propulsion manufacturers (Lake Assault and Torqeedo), we discovered that an electrified propulsion system is already available, aligning with our initial short-term strategy. The entire vehicle replacement schedule, adjusted for the challenges of electrification, is presented in Table 7-1.

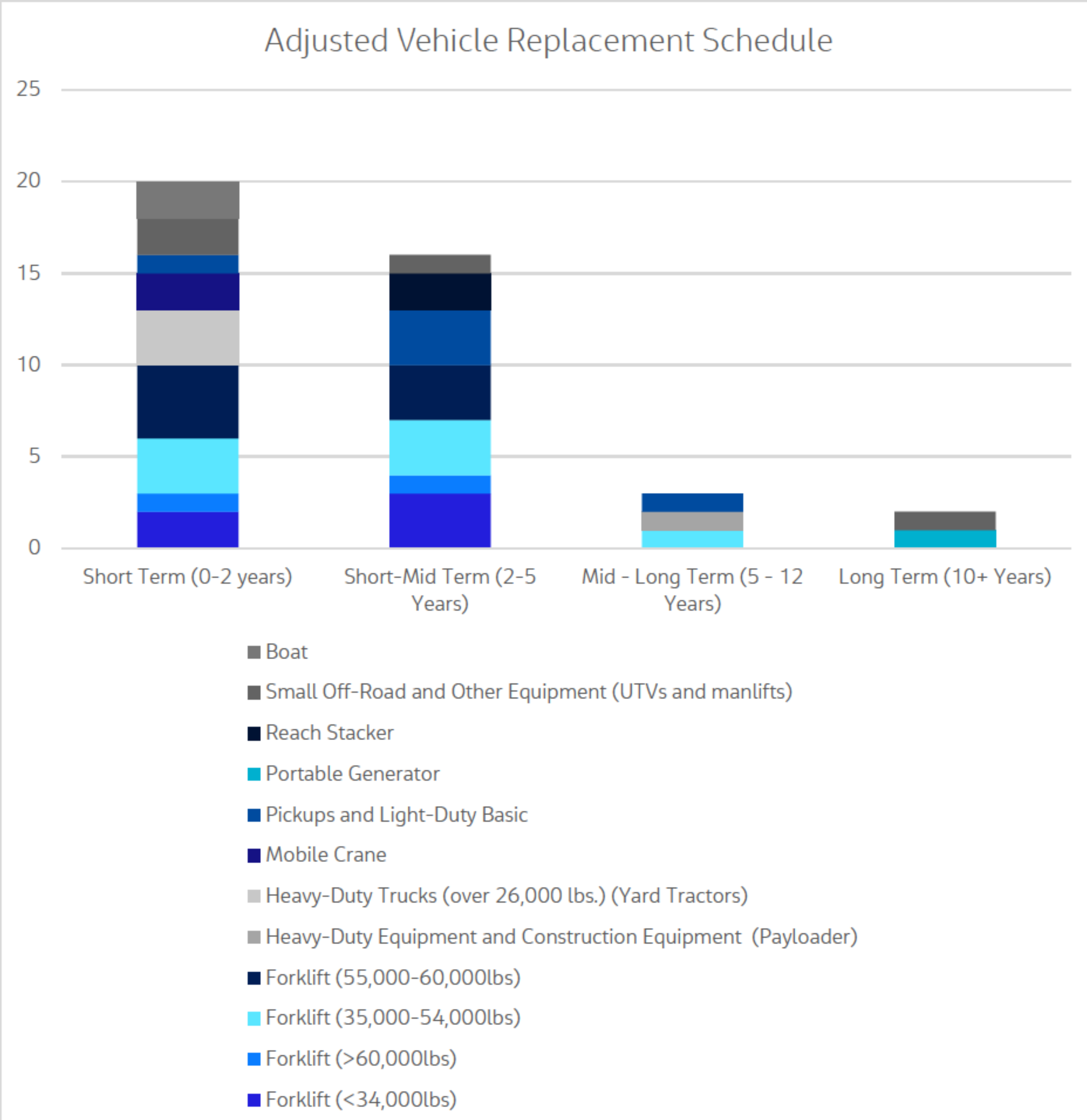
Table 7-1. Adjusted Vehicle Replacement Schedule

Vehicle Type	Short Term	Short-Mid Term	Mid-Long Term	Long Term
Boat	2	0	0	0
Forklift (<34,000 lb)	2	3	0	0
Forklift (>60,000 lb)	1	1	0	0
Forklift (35,000-54,000 lb)	3	3	1	0
Forklift (55,000-60,000 lb)	4	3	0	0
Heavy-Duty Equipment and Construction Equipment (Payloader)	0	0	1	0
Heavy-Duty Trucks (over 26,000 lb) (Yard Tractors)	3	0	0	0
Mobile Crane	2	0	0	0
Pickups and Light-Duty Basic	1	3	1	0
Portable Generator	0	0	0	1
Reach Stacker	0	2	0	0
Small Off-Road and Other Equipment (UTVs and Manlifts)	2	1	0	1
Total	**20**	**16**	**3**	**2**

lb = pound(s)

The analysis of the fleet replacement data has yielded significant insights regarding the timing and rationale for replacing the vehicles. The following summary provides a detailed breakdown of the findings, highlighting the key considerations for each replacement category (Figure 7-9).

Figure 7-9. Adjusted Vehicle Replacement Schedule with Assumed Starting Year of 2030



7.2.1 Short-Term Replacement (2030 to 2032)

Out of the total fleet, a substantial number of vehicles (36) necessitate replacement within the next 5 years, with 16 of them eligible for immediate replacement or within the next 2 years. Within this short-term replacement category, a noteworthy observation is that 81 percent of the vehicles require replacement based solely on their age, while the remaining 19 percent are due to their usage profile within this period. This indicates that the aging factor has a predominant influence on the need for replacement in this timeframe.

7.2.2 Short-Mid Term Replacement (2032 to 2035)

The second largest category comprises vehicles that can be replaced within the next 5 years (16). These vehicles, although still in good condition, are approaching the end of their expected lifespan. In this category, the analysis reveals that 63 percent of the vehicles proposed for replacement in the 2-5 year timeframe are primarily driven by their age factor, while the remaining 37 percent are influenced by their usage profile. It is crucial to consider both age and usage patterns when determining the replacement timeline for these vehicles.

7.2.3 Mid-Long-Term Replacement (2035 to 2042)

Moving to the next set of vehicles, we have a smaller category of those that can be replaced within the next 10 years (3). These vehicles are currently in good condition and have the potential for continued use over the next few years. However, their primary cause for replacement is related to their age, with 100 percent of the vehicles necessitating replacement due to their age factor.

7.2.4 Long-Term Replacement (2042+)

Lastly, we have a category of vehicles that can be replaced long term. This consists of the singular UTV, which was recently purchased in 2022. This vehicle, similar to the previous category is still in satisfactory condition and can be used for a few more years. It is also worth noting that the electrification of the portable generator, which accounts for the last replacement, is also influenced by its electrification difficulty.

7.2.5 Work Barge Electrification

The two work barges at the Port, the Flotsam and Jetsam, were delivered in 2012 by the boat supplier, Lake Assault. The barges were custom built for trash and debris cleanup within the Port and surrounding Cleveland riverways. While the anticipated useful life of the boat's hulls are 25 years, it is anticipated that the powertrain and propulsion systems should be replaced every 10 years, resulting in the current engine and powertrain being considered past their useful life. In the immediate to short term it is recommended that the Port work with Lake Assault to retrofit the two work barges with batteries and electric propulsion systems from supplier such as Torqeedo. This solution would provide the most economically beneficial and feasible option for electrification.

7.2.6 Mobile Harbor Crane Electrification

The two mobile harbor cranes in operation at the Port were procured in 2015. Given the assumed useful life of 20 years our model classified the mobile harbor cranes as a long-term replacement candidates, recommending that the cranes be replaced in the year 2035. Unlike all other land-based vehicle types on our list though the mobile harbor cranes have available upgrades from the manufacturer, Liebherr, to convert the current 100 percent diesel-powered vehicle to a diesel electric hybrid drive. In our discussions with Liebherr the conversion is not only available for the LHM-280-3 cranes at the Port, but also that is readily available and relatively easy to install. Installation windows for the hybrid system conversion was estimated by Liebherr as 6 weeks (about 1.5 months) for assembly and installation of the electric-drive components, including commissioning. Cost per crane is roughly $1.3 million. It is recommended that the port modify their existing two mobile harbor cranes to electric hybrid drive systems once the cold ironing power infrastructure is installed and operational, potentially much sooner than 10 years.

7.3 Capital Costs of Fleet Replacement

After classifying each vehicle as detailed in the section above, a cost of replacement range was determined for each vehicle for procurement cost planning purposes to accompany the infrastructure capital costs overviewed in Section 2. Pricing information was found by either using publicly available information, contacting a dealer for a quote, or estimating based on publicly available information.

Once a 2023 price was assigned to each asset, a 5% annual appreciation rate was assumed. This appreciation rate was used to convert 2023 pricing into a price estimate for the year the vehicle is scheduled to be replaced based on the end-of-life year. This method will provide a high-level analysis, but it important to note the caveats with this approach, and the caveats in general with attempting to project yearly necessary capital expenditures that are necessary to convert to an EV fleet.

1. **Economies of Scale:** Today, EVs are in their infancy and with certain vehicle sectors being more mature than others. As OEMs, sub suppliers, and mining companies scale up production to meet the projected demand long term, vehicle unit prices could and should come down. Today, a premium is paid for EVs, and this is especially true for medium/heavy duty and more specialized vehicle types. While pricing cannot be known in 5 years' time, assuming today's unit pricing will only increase with general inflation could be incorrect. Long term, ICE and EV vehicle prices should continue to converge. However, this is very hard to predict and therefore is not done in this analysis.

2. **Incentives:** There a numerous state and federal subsidies and incentives available to the Port to help fund their transition to EVs. Those incentives, and how they impact vehicle unit costs were not considered in this analysis.

3. **Pricing Inaccuracy:** Due to time constraints, proper quotes could not be generated for all the assets. Additionally, for some of the more specialized vehicles, EV equivalents are not currently available for purchase in 2023. As such, price quotes could be inaccurate.

4. **Buying Power:** Because the Port needs to purchase a large number of vehicles such as the various forklifts, pricing could be negotiated with the OEM or dealer to bring down the per unit price. This was not able to be accounted for in this analysis.

Table 7-2 summarizes the analysis conducted, highlighting the overall costs which are anticipated that the Port will spend on the fleet of EV replacements (per vehicle category). As previously highlighted these figures are estimates and therefore, we produced costs which represent a lower and higher expected replacement cost in line with procurement strategy and replacement intervals.

Table 7-2. Anticipated EV Replacement Cost

	Anticipated EV Replacement Cost							
Vehicle Category	Short Term		Short-Mid Term		Mid-Long Term		Long Term	
	Min ($)	Max ($)	Min ($)	Max ($)	Min ($)	Max ($)	Min ($)	Max ($)
Forklift (<34,000 lb)	$50,000	$110,000	$88,966	$195,725	$0	$0	$0	$0
Forklift (>60,000 lb)	$60,000	$100,000	$71,173	$118,621	$0	$0	$0	$0
Forklift (35,000-54,000 lb)	$135,000	$225,000	$160,139	$266,898	$68,127	$113,546	$0	$0
Forklift (55,000-60,000 lb)	$220,000	$340,000	$195,725	$302,484	$0	$0	$0	$0
Heavy-Duty Equipment and Construction Equipment (Payloader)	$0	$0	$0	$0	$60,558	$121,115	$0	$0
Heavy-Duty Trucks (over 26,000 lb) (Yard Tractors)	$600,000	$810,000	$0	$0	$0	$0	$0	$0
Mobile Crane	$2,602,912	$2,869,710	$0	$0	$0	$0	$0	$0
Pickups and Light-Duty Basic	$40,000	$60,000	$136,414	$225,380	$52,988	$105,976	$0	$0
Portable Generator	$0	$0	$0	$0	$0	$0	$17,959	$25,142
Reach Stacker	$0	$0	$1,067,591	$1,763,424	$0	$0	$0	$0
Small Off-Road and Other Equipment (UTVs and manlifts)	$120,000	$180,000	$17,793	$29,655	$0	$0	$26,938	$44,896
Boat	$100,000	$400,000	$0	$0	$0	$0	$0	$0
Total	**$3,927,912**	**$5,094,710**	**$1,737,802**	**$2,902,188**	**$181,673**	**$340,637**	**$44,896**	**$70,038**

lb = pound(s)

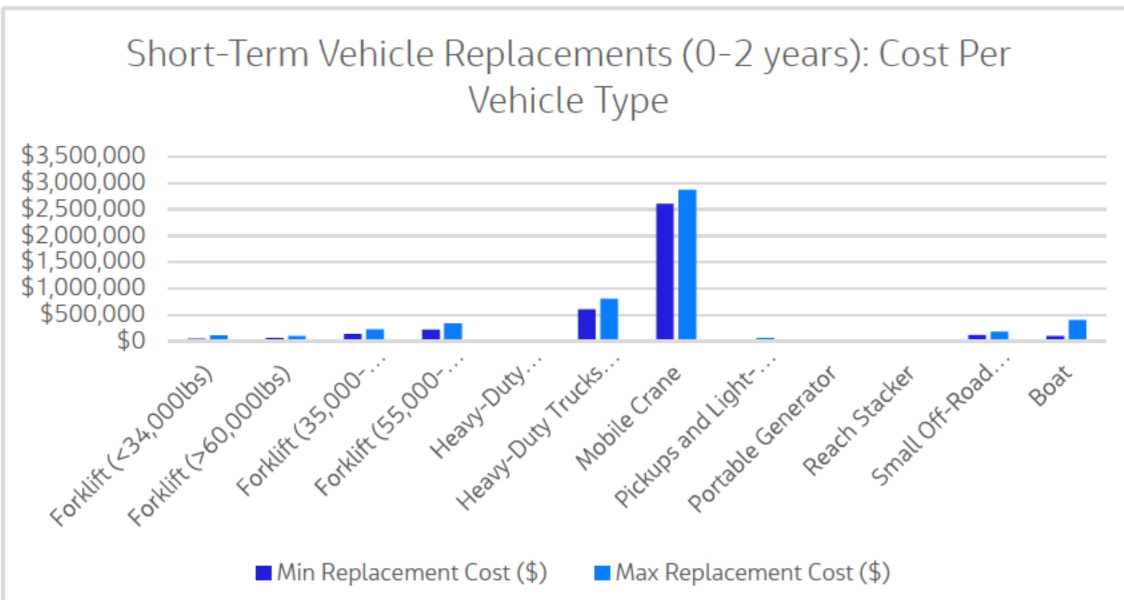
The table analysis reveals a compelling insight over the extended period of 12+ years to achieve a 100% decarbonized fleet. It is estimated that the Port will spend between $5.9-$8.4 million for a thoughtfully devised long-term replacement strategy.

7.3.1.1 Short Term

It has been projected that the Port is recommended to make the most substantial investment for the fleet replacement in the short-term phase from 2030 to 2032, which is significantly greater than any other period. The estimated net expenditure during this timeframe is expected to range between $3.9 million to $5.1 million, encompassing a significant 49% of the entire fleet (Figure 7-10).

Notably, the heavy-duty equipment, particularly the mobile crane electrification, will account for most of this expenditure, comprising a considerable 66% of the total fleet replacement budget within this 2-year period. The remaining allocation will be attributed to the yard tractors (15%), various forklifts (12%), pickups (1%), manlifts (3%) and boats (3%), reflecting a reasonable distribution given the range, age and usage of the remaining vehicles.

Figure 7-10. Short Term Year Vehicle Replacement, Cost per Vehicle Type



7.3.1.2 Short-Mid Term

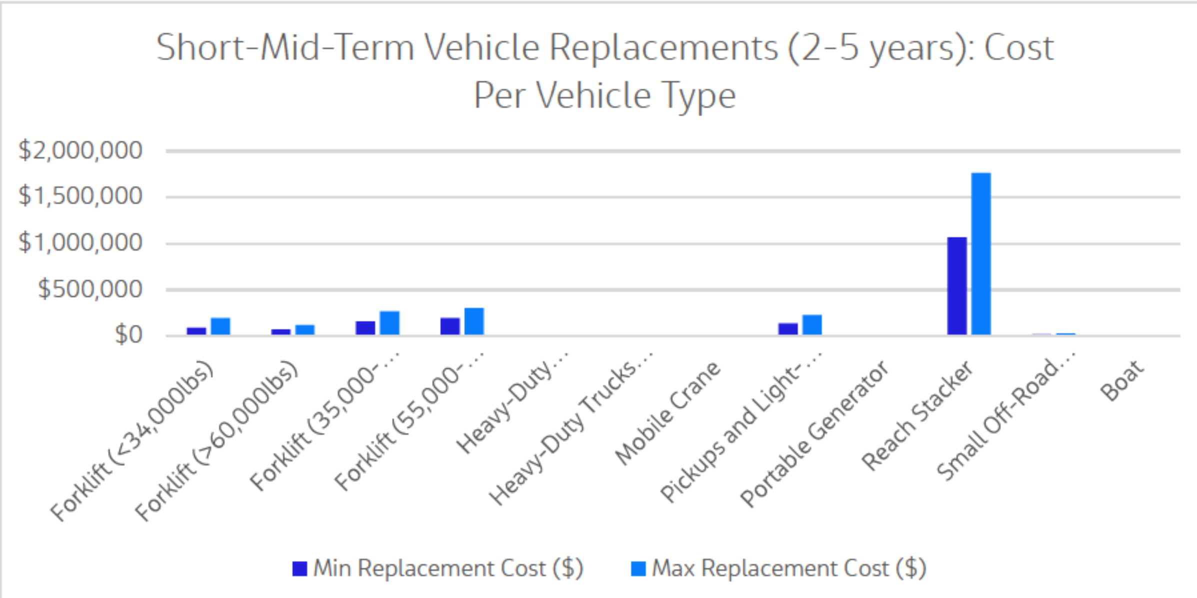
During the short-mid-term years from 2032 to 2035, we anticipate the Port to spend in the region of approximately from $1.7 million to $2.9 million. A notable portion of this budget is dedicated to the acquisition of new reach stackers, a crucial aspect of the Port's fleet modernization initiative. Given the current developing stage of these vehicles in the market, with limited available models, we anticipate an expenditure ranging from $1 million to $1.7 million, as illustrated on Figure 7-11. Notably this allocation accounts for a significant share of approximately 61% of the overall budget earmarked for this period.

Further analysis reveals a detailed breakdown of the budget allocation for other vehicular categories:

- Ten forklifts constitute a notable 30% of the share, distributed amongst all categories of lifting capabilities amongst the fleet.
- Two pickups and one SUV collectively represent 8% of the share.

- A single UTV encompasses the final 1% of the budget allocation, highlighting its targeted utilization for specialized purposes.

Figure 7-11. Short-Mid-Term Year Vehicle Replacement, Cost per Vehicle Type

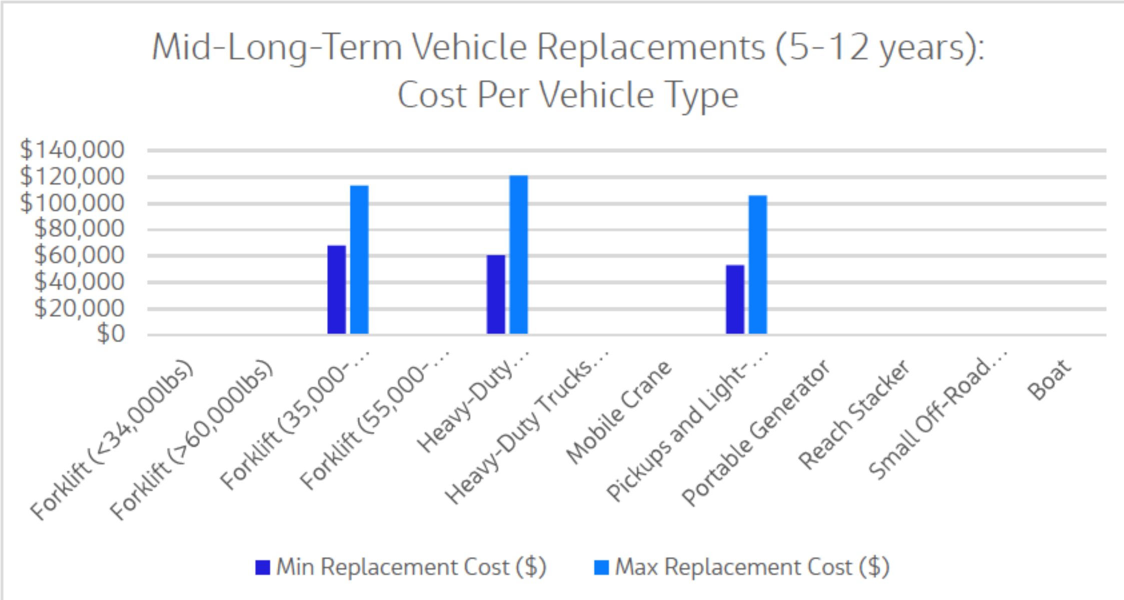


7.3.1.3 Mid-Long Term

The mid-long-term fleet replacement strategy reveals insightful data based on a total of 5 vehicles scheduled for replacement. Despite the significance of this mid-long-term strategy, it is worth noting that this period is projected to witness the second least amount of expenditure on vehicle replacement costs. The total projected spend for this period is expected to fall within a range of $180,000 to $340,000, which is largely due to the decision to prioritize the electrification of the work barges' propulsion in the short-term strategy, as opposed to the more expensive option of replacing both boats entirely (Figure 7-12).

The fleet replacement strategy for the mid-long-term period involves the scheduled replacement of a single forklift, which represents 38% of the total vehicles to be renewed during this phase. A solitary payloader, accounting for 33% of the targeted fleet renewal. Additionally, one SUV is included in the mid-long-term fleet upgrade, contributing 29% to the overall replacement effort.

Figure 7-12. Mid-Long-Term Year Vehicle Replacement, Cost per Vehicle Type

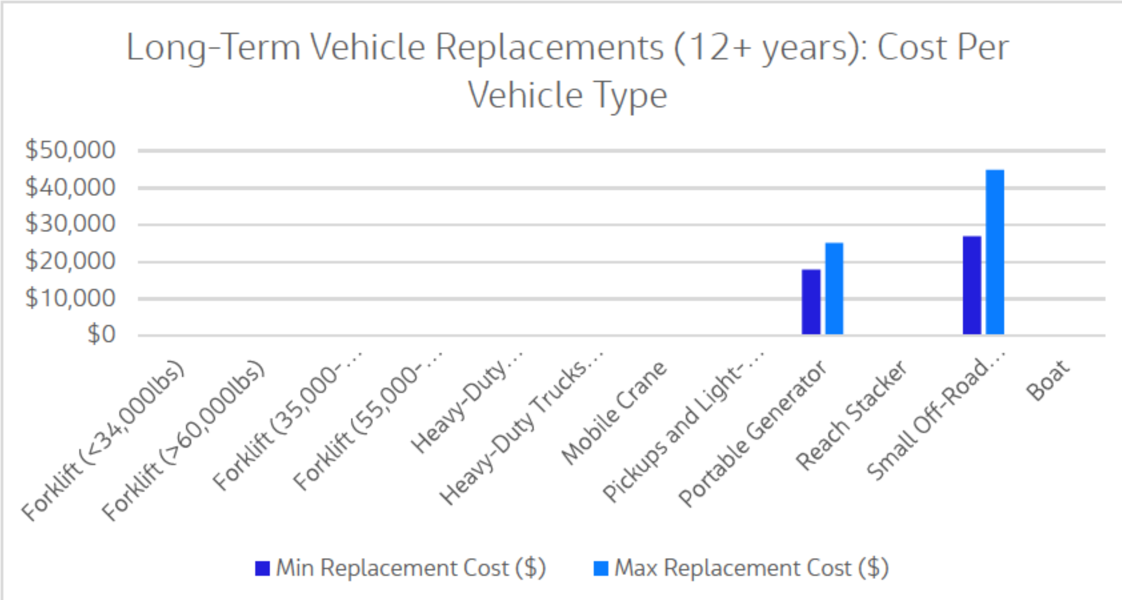


7.3.1.4 Long Term

The long-term replacement strategy, spanning from 2042 onward, stands out as the least financially substantial phase within the overall fleet replacement plan. As the electrification of the mobile cranes has been brought forward to the short-term replacement period, which initially attributed to 99%, it is now estimated that the expenditure during this period will range between $45,000 to $70,000.

Those vehicles which remain to be replaced long term are one electric generator and one electric UTV, which count towards 40% and 60% of the total earmarked expenditure required as illustrated on Figure 7-13

Figure 7-13. Long-Term Vehicle Replacement, Cost per Vehicle Type



7.4 Incentives

Today's hurdle to electrification for organizations, both private and public, is the capital cost of eVs compared to their diesel equivalents. Long-term projections predict the price disparity between eVs and ICE vehicles will tighten as OEMs achieve economies of scale and as material and component supply chain mature; however, the need to reduce emissions cannot wait. EV needs to be deployed now. As such, State and Federal government have created incentive and grant programs to help fleets afford EV today. Ohio is committed to reducing emissions and deploying eVs and has created a number of incentive programs that can be used by the Port to reduce their costs when buying light-, medium- and heavy-duty vehicles. Those state incentives can be combined with Federal incentives to further reduce Port direct capital expenditures. Appendix K details the major Federal and State incentives that are available to the Port.

8. Vessel Cold Ironing Transition

The process of developing a plan for the implementation of shore power includes several steps. First, an analysis of the fleet calling at the port must be performed. The call records should include a record of the ship's name, the berth location, and the time the ship spent at berth. An analysis of the ship type and the average power demand for the ship while in port to support its loading and unloading operations can be performed. From this, an energy demand in kilowatt-hours can be calculated. Once the overall energy demands are known for each ship, the demands by berth can be analyzed as well to determine what supply needs to go to what berth. The detailed call and energy analysis is further outlined and shown in Appendix H.

Once the power demands are calculated for each berth, the distribution of that power to the berths will be studied. A shore power system consists of multiple parts including the source of power from the substation, a load transformer and switchgear, and a cable management system (CMS) to connect the vessels to the power. Each of these components can have many different options and configurations. These configurations will be studied and a plan for implementation developed.

The age and electrical capabilities of the fleet will need to be studied as well. Absent from regulatory pressure, most older vessels will continue to be operated under ship's power while in port as the costs to upgrade the vessel to support a shore power connection is expensive and requires the ship to be taken from service, meaning it will miss calls. A study of the existing fleet and the existing electrical capabilities was performed.

These vessels have a range of industry standard size classifications from Small Handy Size up to Lake Freighter (Capesize). Each of these different classifications will have a different power demand. Table 8-1 defines the size ranges that are used in this study, and Figure 8-1 shows the vessels' relative sizes.

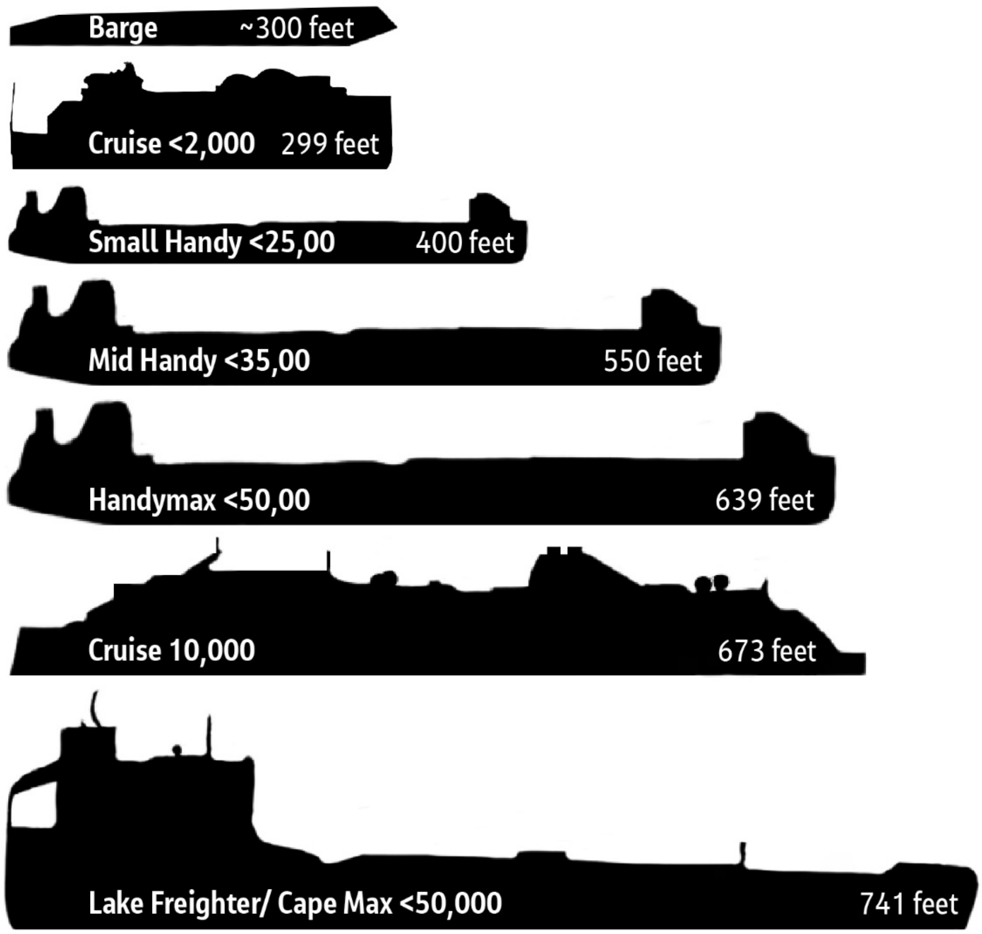
Table 8-1. Vessel Categories

Vessel Category	Max Vessel DWT (tons)	Vessel LOA (ft)	Number of Vessels
CRUISE < 2000	2,000	< 350	4
CRUISE 10000	10,000	< 700	1
SMALL HANDY	< 25,000	< 600	61
MID HANDY	<35,000	< 650	47
HANDYMAX	< 50,000	< 650	30
LAKE FREIGHTER (CAPEMAX)	> 50,000	> 650	9
BARGE	Varies	Varies	8

DWT = deadweight tonnage
LOA = length overall

The limits above for the Handy series of vessels are a bit different from the industry standard Handy sized vessels as the length and beam are controlled by the Welland Canal. The ships are a bit longer than some Handy sized vessels to get the same DWT capacity. These vessels are referred to as Seawaymax vessels. Electric demand for the Handy sized vessels is well known and therefore our analysis is based on the Handy sized vessel designations. Also, the Lake Freighters are a unique class of vessel. These vessels are designed and built strictly for Great Lakes commerce. They are too large to pass through the controlling canal locks. The closest class of vessel for which industry standard power demands are known is the Capemax vessel. The power demands for a standard Capemax are used for these vessels.

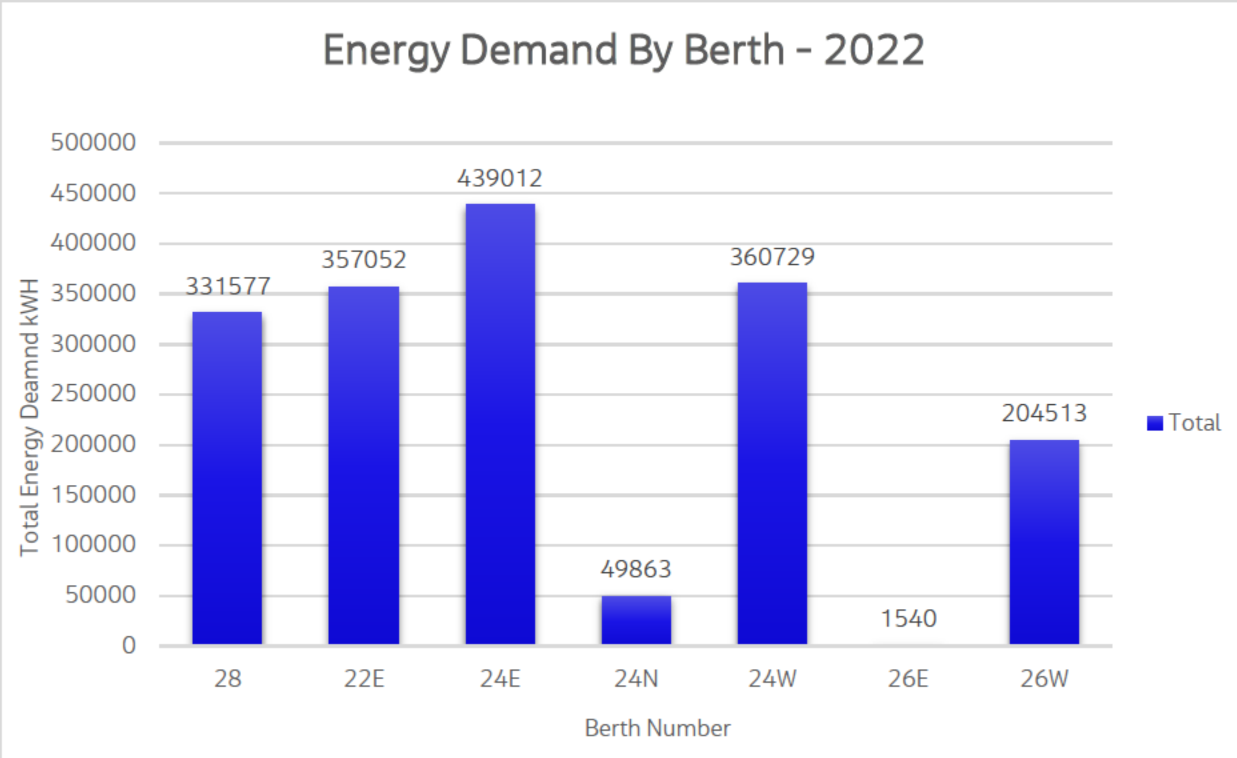
Figure 8-1. Vessel Categories

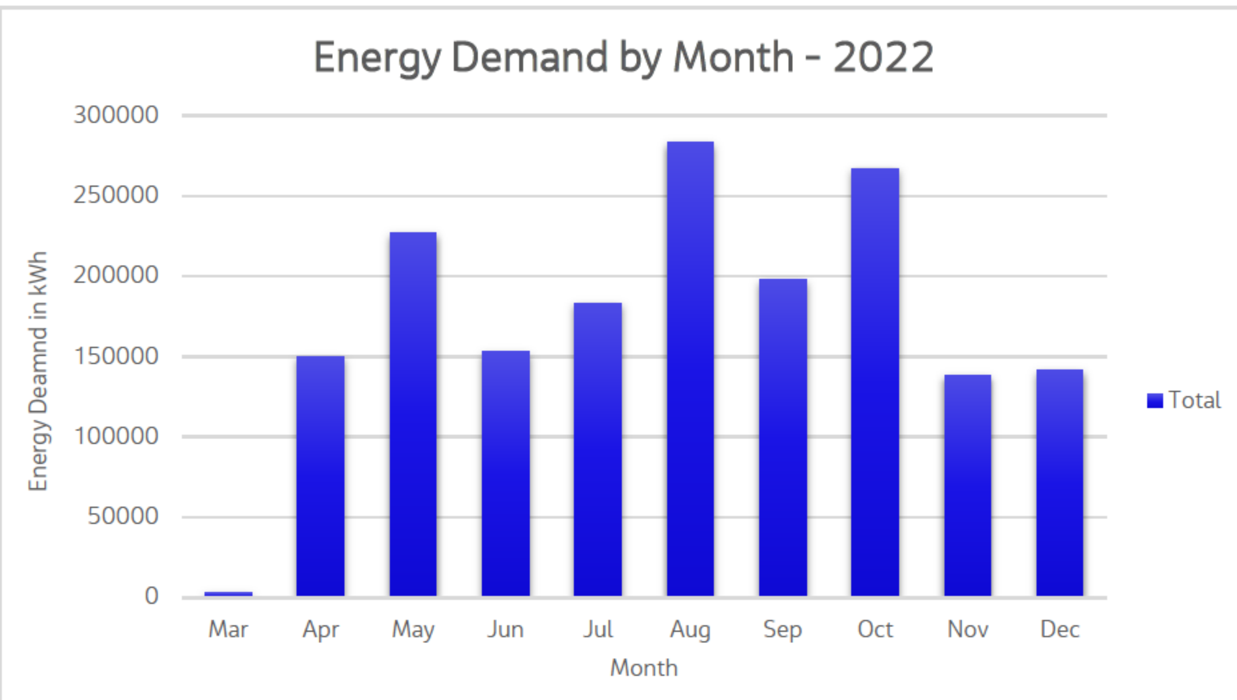


8.1 Projected Electrical Demand

The charts presented in this section represent the electrical demand, monthly over the course of 2022 and the electrical demands by berth for the same period. It should be noted, that the Capemax vessels do not call at the berths shown on the charts. Figure 8-2 shows the projected electrical demand by berth and by month, if all current vessels that call to the Port were to be transitioned to cold ironing.

Figure 8-2. Projected Energy Demand by Berth and Month, using 2022 Call List





The history of vessel calls is a good place to start with respect to assessing the power needs at the berths for concurrent ship calls, but it cannot fully predict the future peaks related to shore power demands. The port understands this and has given upper limit scenarios to be analyzed to size the shore power based upon peak loading. These scenarios include a facility wide maximum, one cargo berth maximum, maximum across all cargo berths, and a maximum cruise berth. The maximum across all berths is assumed to be two Capemax cargo vessels. The maximum for mobile harbor cranes facility wide is assumed to be a total of three cranes. The assumed power requirements of 670 kW per mobile harbor crane is factored herein as well. The total peak power demands for each of these scenarios is shown in Table 8-2.

Table 8-2. Maximum Operational Scenarios Peak Power Demands

Operational Scenarios	Cruise Ship (kW)	Handymax Cargo (kW)	Mobile Harbor Crane (kW)	Total (kW)
Max Facility Wide	2450	740	2010	5200
Max Individual Cargo Berth	0	370	1340	1710
Max All Cargo Berths	0	740	2010	2750
Max Cruise Berth	2450	0	0	2450

Although the two cargo berth maximum occupancy scenario is the design scenario for the future shore power system, additional higher-occupancy scenarios were also examined. Of particular interest are the scenarios with three cargo vessels berthed simultaneously and with all mobile cranes working at the same time. This would represent the maximum possible electrical load for cargo operations. Over the 3 years represented by the data, three cargo ships have been in berth five times. This represents a relatively low percentage of occurrence, with only two events per year. In all instances of three cargo ships at berth, both Berth 24E and 24W are occupied. The third berth is 22E, 26E, or 24N. As these data demonstrate, this scenario is unlikely and it would not be economical to design the shore power system for an infrequent occurrence such as this. As such, the assumption of two cargo vessels is used for this analysis.

When planning the overall power requirements of the facility, these scenarios should be considered. It should be noted that individual circuits for both the shore power and the cranes as these cannot be on the same circuit. The calling fleet analysis and energy demand analysis is shown in more detail within Appendix H.

Figure 8-3. Ocean Navigator Docked at Berth 28A

8.2 Future Implementation of Cold Ironing

Based on the predicted growth of shore power and the maximum shore power loading scenarios, there are steps to implementing the overall shore power system. Switchgear for each berth will need to be purchased and installed. This switchgear will power the ship shore power systems as well as the crane systems. The cranes will need to be powered from a system that is different from the ship systems as the IEC/IEEE standards do not allow this.

Based on the assessment performed in this study, there are several potential solutions and pathways to implement the shore power system. As shown previously, the system can be envisioned as consisting of separate systems. These individual systems include the utility transformer, the switchgear for each electrified berth, the cabling carrying the secondary power to the berth, the socket box or connection point for the cables, and the CMS. In addition to these items, there is physical infrastructure required to support the system such as duct banks and manholes. The recommendation for each of these systems follows.

8.2.1 Switchgear Recommendations

The switchgear located at Warehouse A will convert the incoming 12-kV CPP power source and transmit the power at 6.6 kV to the shore power connections or socket boxes. The switchgear can be configured in a number of physical formats including pad-mounted or containerized solutions. As the industry matures and the demand for shore power systems increases, the number of different vendors increases. As such, the recommendation for the switchgear system will focus on physical configurations.

It is recommended that a singular switchgear solution be used for the shore power at the Port of Cleveland in lieu of a quayside containerized switchgear.

8.2.2 Electrical Infrastructure

The Port has previously developed a system of empty duct banks that is routed from a central point by Warehouse A and travels along each berth. The duct bank runs along the face of each berth, and manholes are strategically placed to facilitate pulling conductors through the duct bank, as well as placement of the vessels.

The socket boxes should be located near the ship's shore power connection points. Typically these points are located near the quarter points of the vessel, both fore and aft, based upon the architecture of the vessel. Cargo vessels rarely have the connections at mid ships because they would interfere with cargo loading and unloading operations. Based on this, two socket boxes should be located along the berth face at locations that coincide with the quarter points of the vessels.

The socket boxes can have a variety of configurations based on the needs of the port and other factors. The boxes can be surface mounted in a weatherproof enclosure and protected by bollards from equipment and vehicular traffic. The boxes may also be mounted below the deck in a pit structure. This is problematic from a maintenance perspective with water intrusion due to high water tables. It is recommended that aboveground socket boxes be used for this facility.

To accommodate the variability of the location of the ship power connectors, the CMS (discussed in the following section) should be able to travel in either direction from the socket box. To protect the cables along the deck, a shallow trench with a traffic-rated lid running parallel to the berth should be installed. The trench should run in either direction from the socket box for a distance of 100 feet. This will provide maximum shore power availability for most vessels that call at the port.

At each cargo berth, provisions should be made for the electrical connections of the mobile harbor cranes. Similar to the shore power cables, the mobile harbor crane cabling should be protected in a trench with heavy-load–rated covers. This trench should cover all allowable positions of the mobile harbor cranes. The trench should be a minimum of 18 by 18 inches and should have a drain to allow for dissipation of any surface water that finds its way into the trench.

8.2.3 Cable Management System

Another step in the development of the system will be to purchase the CMS devices to facilitate the actual connection of the vessels to the system. The shore power connection from the socket box to the ship's connections is accomplished by a CMS. The CMS connects to the shore power socket box, and then uses a jib arm supporting a saddle to allow the cables to drape across the gap between the bulkhead face and the ship. The cables for a catenary that allows for ship movement without putting strain on the cables.

Three mobile CMSs are recommended because this allows the maximum power scenario to be facilitated. A 2- by 2-foot trench should be constructed, originating at the existing shore power manholes and traveling a short distance in each direction. The trench will have heavy-load–rated lids. The trench will allow the cable connection from the CMS to the shore power termination point in the manhole to be covered and protected from traffic along the berth during ship operations. The trench may be extended the full length of the berth to allow for the mobile harbor crane power cables' protection as well. Also, to facilitate the multiple longitudinal positions of the ships' power connectors, the CMS should be mobile. A system such as the Cavotec Powermove can be implemented. Two mobile CMSs should be acquired and used to provide power to two berths at the same time. Based on the distance between the berths and the potential need to move the CMS long distances, a tow-behind unit is preferred over a self-propelled one. CMSs available on the market are detailed within Appendix I.

8.2.4 Implementation Plan

The shore power system recommended is a modular system that will allow for a phased implementation. The berth electrification can take place in phases, allowing for additional berths to be brought online as demand increases and funding for the development becomes available.

To start, the central distribution point near Warehouse A should be cleared and prepared for the installation of the switchgear. The feed from the utility should be installed and the transformer placed in an area that will be convenient for future upgrades as more berths come online. The area should also be cleared and reserved for all future shore power switchgear modules. Fencing and other physical separation should be developed at this time as well.

The approach to implementing shore power should be on a berth-by-berth basis, and based on the demand and availability of shore power connections for the vessels calling at that berth. It is recommended that the two shore power connectors and trenches be constructed as each berth is brought online for cold ironing. This will allow for the construction to take place under one mobilization and thus minimizes the disruption to operations at the berth. Trenches for the mobile harbor cranes can also be constructed during the mobilization for the

It is recommended that Berth 24E and 24W be electrified first with Berth 22E following behind.
Berths 24N and 26N can be implemented after. The cruise berth, Berth 28, can be electrified at any time during the process, based on the availability of power to the port from the utility as the cruise berth has significantly higher demand than the cargo berths.

9. Solar Power Generation Infrastructure

A key element on the transition to ZE for the Port will be to understand how best to leverage onsite generation and renewables to supply power to both the battery electric fleet and the cold ironing needs of the cargo and cruise vessels. Focusing on the centralized Warehouse A electrification hub area, Jacobs has identified potential technologies, specifically solar, that could provide tangible and economical power generation for the Port's facilities. For solar Warehouse A, Warehouse 24, and Warehouse 26 roofs offered the best basis for a large continuous solar arrays.

Conceptual Helioscope solar models were generated for Warehouse A, Warehouse 24, and Warehouse 26 to get high level energy estimates (Figure 9-1 through Figure 9-4 and Table 9-1). The systems utilize Trina Solar, TSM-580NEG19RC.20 solar modules, the standard high efficiency module typically recommended for Jacobs' rooftop installations, and use a flush mounted racking system. The full site has an estimated total capacity of 4 MW, and would produce an estimated 4.8 GWh each year. The rooftop PV system uses a racking system, in which the solar modules are mounted flush to the rooftop. Flush mount racking is most seen on sloped roof applications.

It is assumed that structural load capacity factors for all three warehouses may not be suitable structurally to support the additional solar panel loading. Our recommendation would be to install vertical metal posts from the existing truss framing at 24'-0" on center and add additional support above the roof to support solar panel assemblies. This would eliminate adding additional support below and minimize the amount of penetrations thru the roof. It is also recommended that a completely new roofing PVC membrane is installed concurrent to the installation of the structural supports for the solar panels to ensure that the system is installed to preserve roof warranties with both ballasted and mechanically attached systems.

Typically rooftop solar systems are a 25+ year asset and Rooftop solar timing is best when paired with a new or newer roof to align system lifetimes and to ensure that avoid later costs to e.g. move solar array during a reroofing event. Other benefits of installing a membrane roofing system with solar is that solar modules are increasingly utilizing "bifacial" modules which produce energy on both the front and back side of the modules. Reflective roof surface paired with bifacial modules makes a portion of the roof cost eligible for the Investment Tax Credit (ITC; Internal Revenue Service Private Letter Ruling). This is an important distinction that can allow reroofing and roof repairs to be eligible to be paid for tax credits related to installing the solar PV system. This is further discussed in Section 9.7, "Available Solar Incentives."

Figure 9-1. Flush Mount Rooftop Solar Helioscope Solar Model for Entire Site

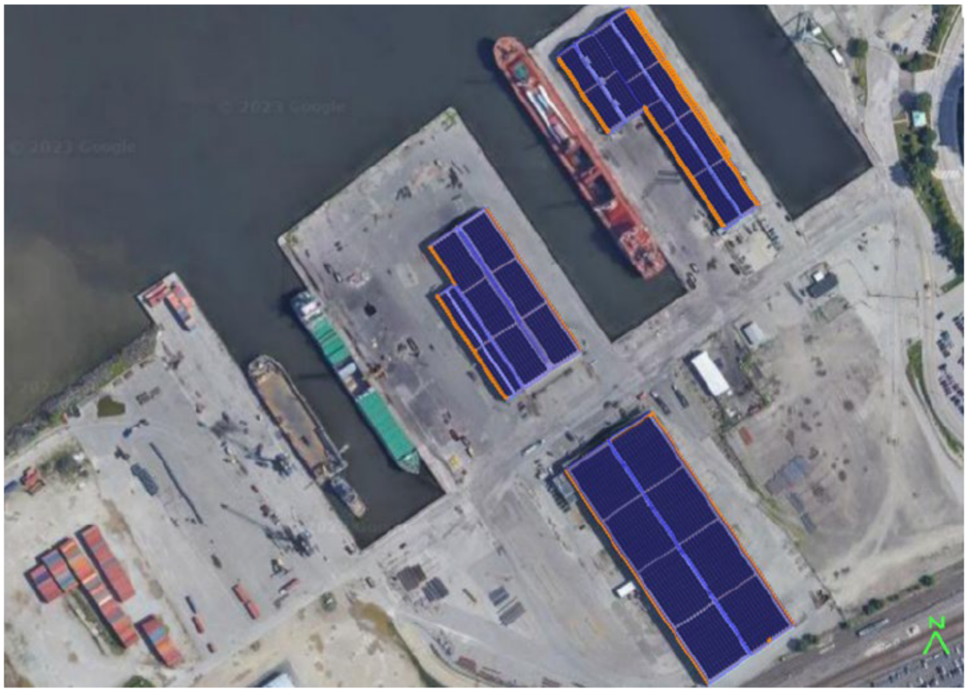


Table 9-1. Rooftop Solar Model Performance for Whole Site

	Flush Mount
Module Wattage (WDC)	580
Number of Modules	6,875
Estimated System Wattage (MWDC)	4
Estimated Annual Output (GWh)	4.8

WDC = watt(s) direct current

Figure 9-2. Whole Site Flush Mount Rooftop Solar Estimated Monthly Energy

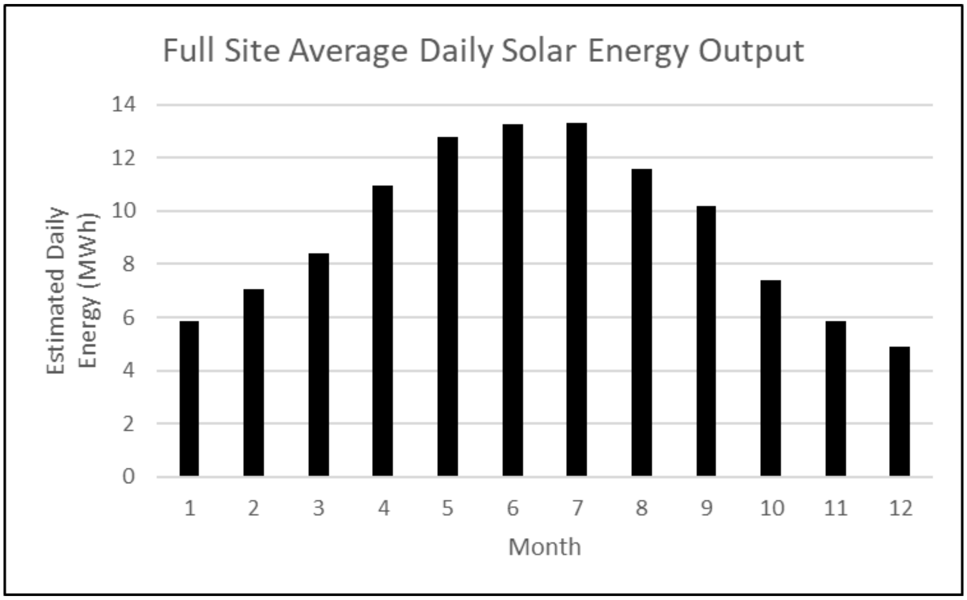


Figure 9-3. Whole Site Flush Mount Rooftop Solar Estimated Average Daily Energy Output by Month

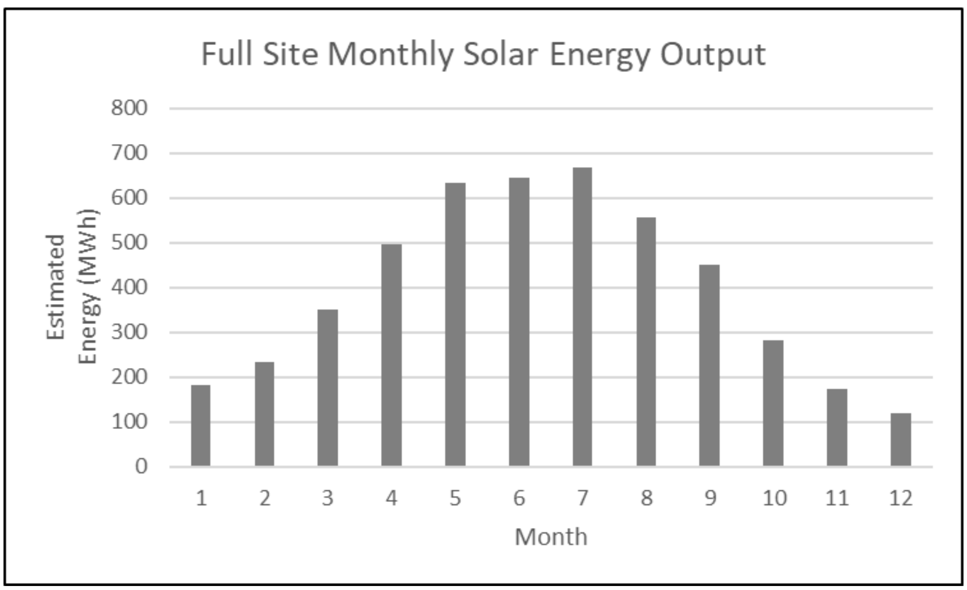
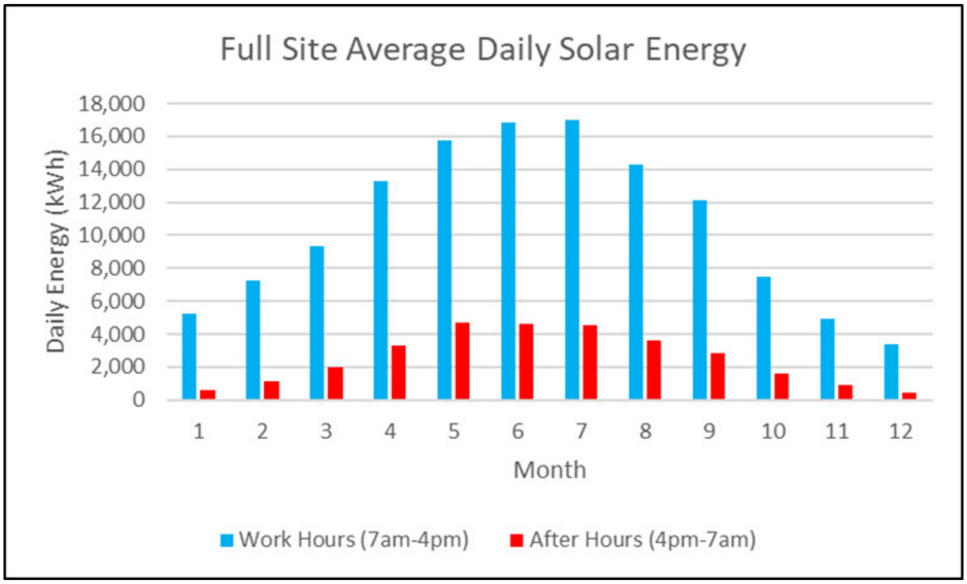


Figure 9-4. Whole Site Flush Mounted Solar Production for On- and Off-Shift Times



9.1 Warehouse A Solar Photovoltaic

Warehouse A is the focal point of the electrification project, and also presents the largest surface for a considerable solar array. The conceptual system used for this analysis utilizes the same high-efficiency bifacial Trina Solar, TSM-580NEG19RC.20 solar module. The system will have a nameplate capacity of roughly 2.1 MW and will generate about 2.5 GWh of energy annually (Figure 9-5).

Figure 9-5. Flush Mount Rooftop Solar Helioscope Solar Model-Warehouse A

Table 9-2. Rooftop Solar Model Performance for Warehouse A

	Flush Mount
Module Wattage (WDC)	580
Number of Modules	3,600
Estimated System Wattage (MWDC)	2.1
Estimated Annual Output (GWh)	2.5

WDC = watt(s) direct current

As shown on Figure 9-6 and Figure 9-7 and in Table 9-2, the flush mounted system will generate approximately 2.5 GWh per year. In peak summer months it will generate up to roughly 350 MWh, but in winter months it will generate less than 100 MWh.

Figure 9-6. Flush Mount Rooftop Solar Estimated Monthly Energy Output

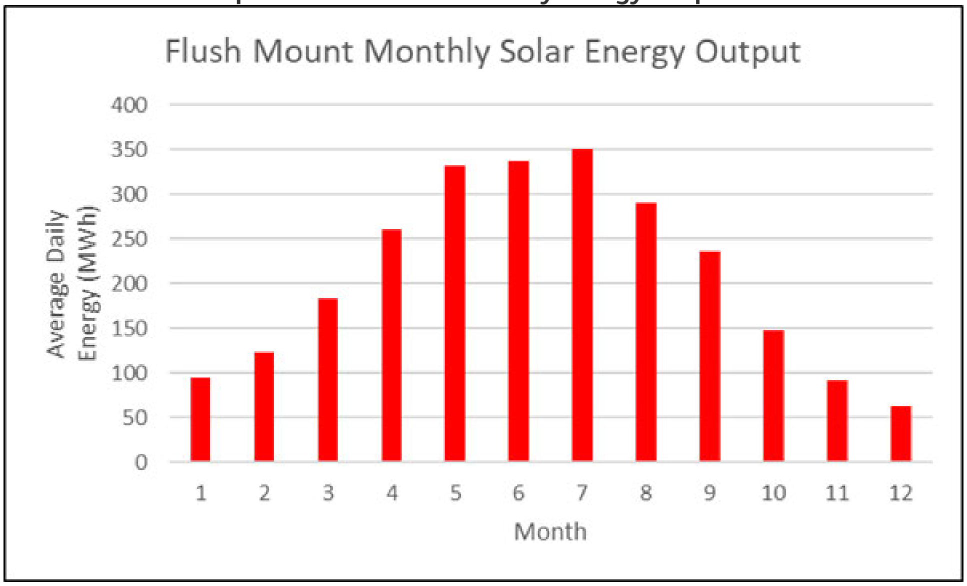
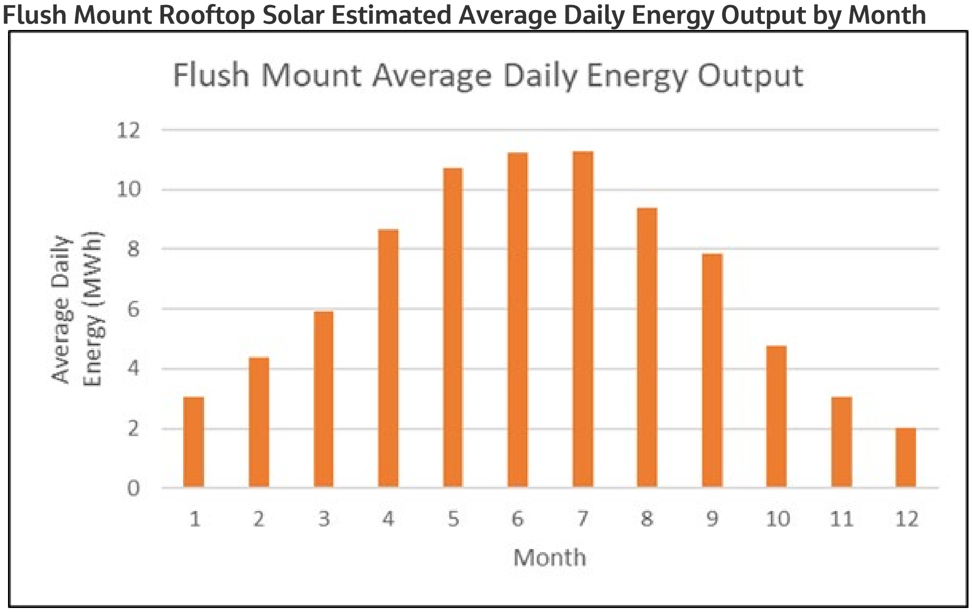


Figure 9-7. Flush Mount Rooftop Solar Estimated Average Daily Energy Output by Month



In addition to the average daily and monthly energy production data above, Jacobs also quantified the split of solar produced energy during on- and off-shift times of day.

9.2 Warehouse 24 Solar Photovoltaic

Warehouse 24 is a large warehouse located within the Port housing majorly bulk cargo. The roof is a sloped roof that presents a great basis for a solar array to contribute to the energy needs of battery electric equipment charging and cold ironing due to its proximity to Warehouse A (Figure 9-8 through Figure 9-10 and Table 9-3).

Figure 9-8. Rooftop Solar Helioscope Solar Model-Warehouse 24

Table 9-3. Flush Mount Rooftop Solar Model Performance for Warehouse 24

	Flush Mount
Module Wattage (WDC)	580
Number of Modules	1,675
Estimated System Wattage (MWDC)	0.9
Estimated Annual Output (GWh)	1.2

WDC = watt(s) direct current

Figure 9-9. Flush Mount Rooftop Solar Estimated Monthly Energy Output

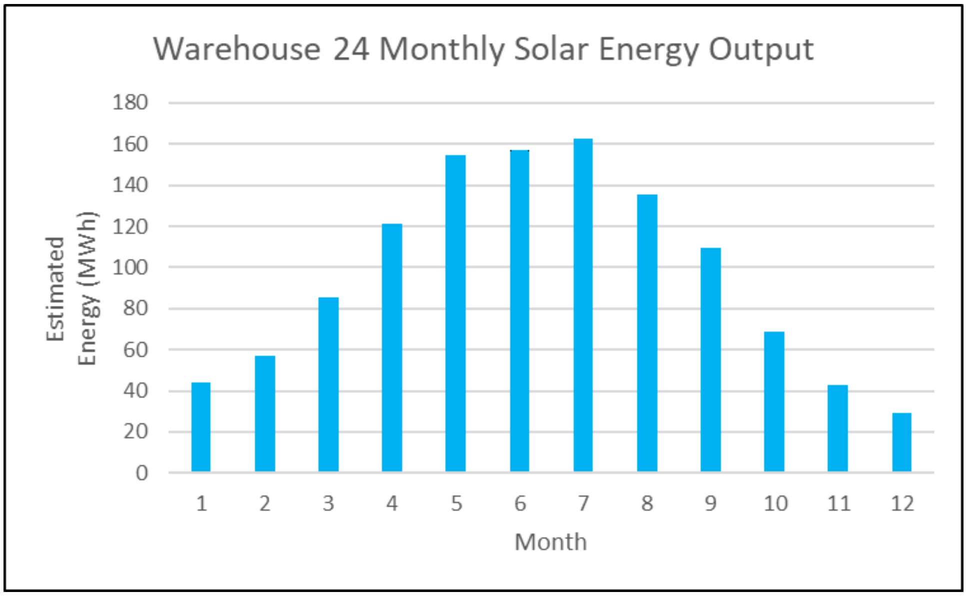
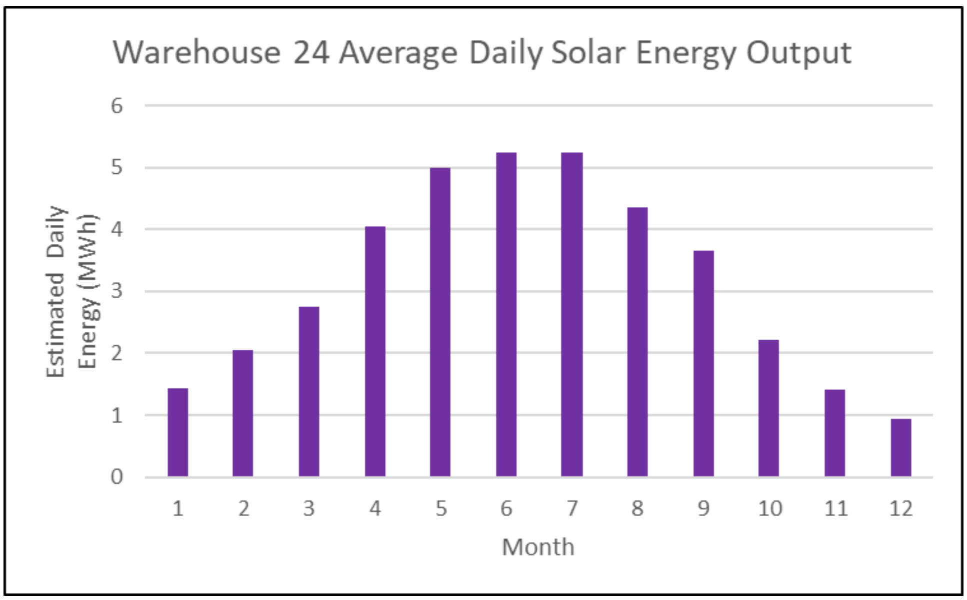


Figure 9-10. Flush Mount Rooftop Solar Estimated Average Daily Energy Output by Month



9.3 Warehouse 26 Solar Photovoltaic

Warehouse 26 is a large warehouse located within the Port housing majorly bulk cargo, in addition to the U.S. Customs and Border Protection areas and offices. The roof is a sloped roof that presents a great basis for a solar array to contribute to the energy needs of battery electric equipment charging and cold ironing due to its proximity to Warehouse A (Figure 9-11 through Figure 9-13 and Table 9-4).

Figure 9-11. Rooftop Solar Helioscope Solar Model-Warehouse 26

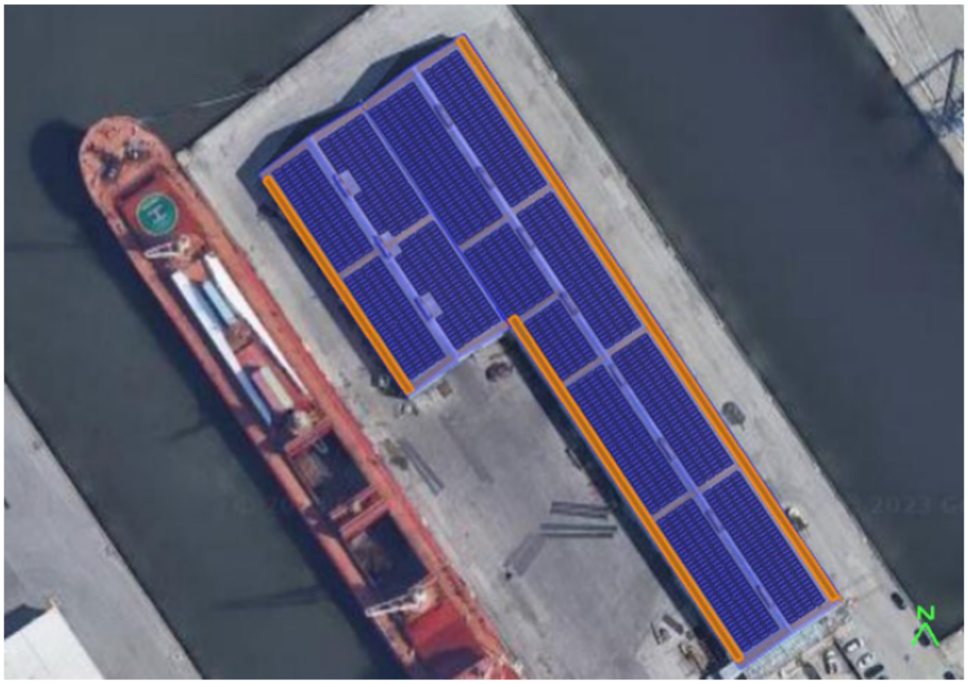


Table 9-4. Rooftop Solar Model Performance for Warehouse 26

	Flush Mount
Module Wattage (WDC)	580
Number of Modules	1,600
Estimated System Wattage (MWDC)	1.0
Estimated Annual Output (GWh)	1.1

WDC = watt(s) direct current

Figure 9-12. Flush Mount Rooftop Solar Estimated Monthly Energy output

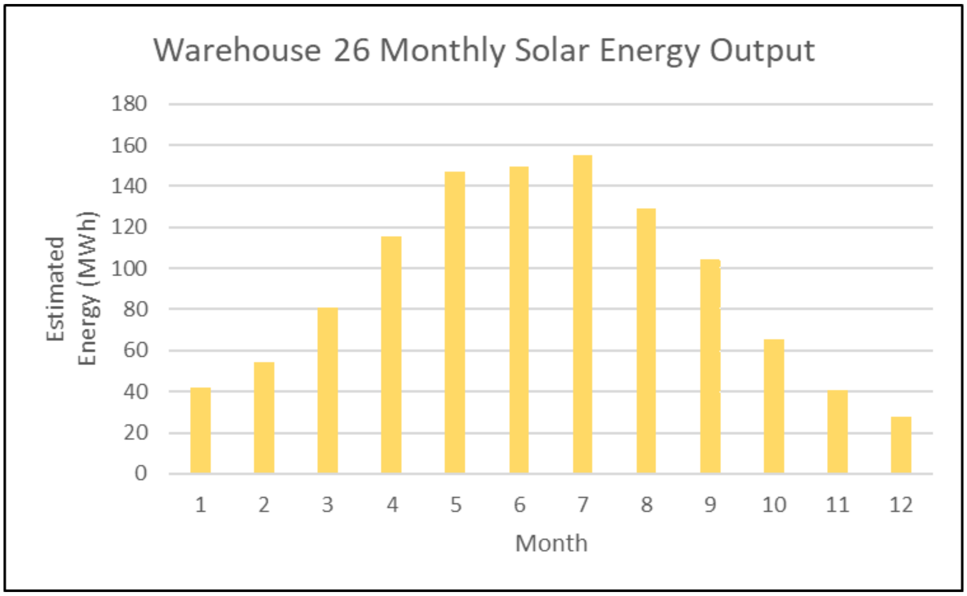
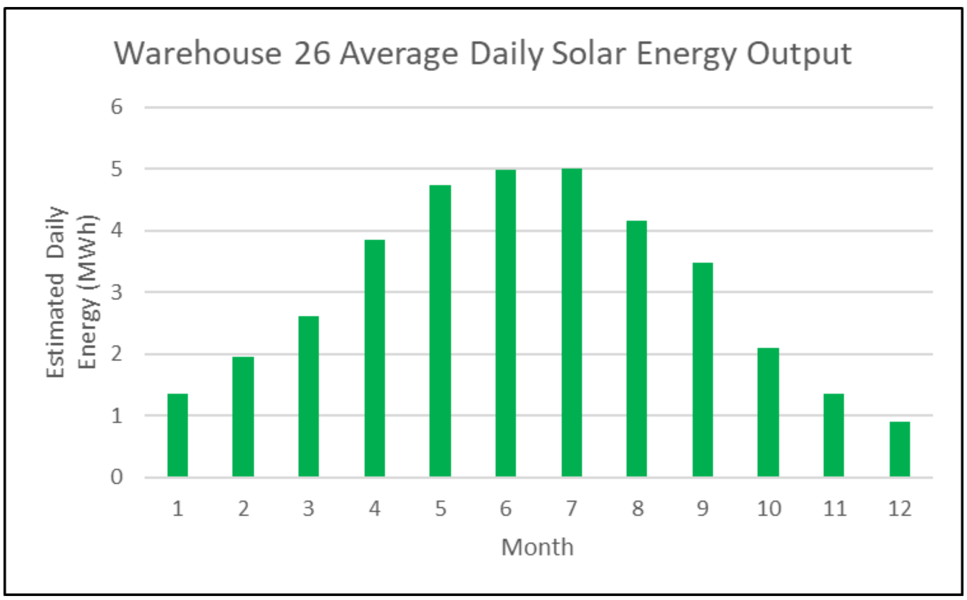


Figure 9-13. Flush Mount Rooftop Solar Estimated Average Daily Energy Output by Month



9.4 Solar Glint and Glare Considerations

A formal daylight and panel angle study is being performed by Jacobs to ensure feasibility of a large solar structure on top of Warehouse A, though it is assumed that this building represents a suitable location for new solar modules to be installed. Commercial-grade solar modules, by enlarge, are now manufactured with an anti-glare coating. Such measures have allowed for over 20 percent of airports in the U.S. to install solar at their facilities. Solar at airports must first pass an FAA-required glint/ glare study prior to installation. Such as study can be done for this site to mitigate any solar glint/ glare concerns with Burke lakefront airport.

9.5 Seabird Deterrents and Prevention

The implementation of a robust operation and maintenance plan will be required to ensure the solar installation on Warehouse A is adequately protected from seabirds and weather. Dust buildup and bird droppings on solar modules can severely impact solar system performance. It is essential to identify an effective seabird mitigation strategy to prevent gathering and nesting. Some of the different bird deterrent options including automated laser systems, bird spikes, acoustics, and cleaning systems are detailed as follows.

9.5.1.1 Automated Laser System

In recent years, one new bird mitigation strategy that has grown is using laser technology to deter birds away from solar arrays. This technology was originally developed to deter birds away fruit crops and food production facilities but is now being adopted for rooftop solar applications. It works by installing a laser device onto the rooftop and programming it to point the laser at birds as they land on solar modules. Birds see the laser as a threat which causes them to fly away. The laser device is not effective against birds of prey; however these species are a minimal concern compared to seabirds and other water-based bird species.

Laser systems are fully automated and can be powered via the grid or connected to a solar charged battery system. These systems have proven to be extremely effective, however it does increase the overall system cost in comparison to other bird mitigation strategies.

9.5.1.2 Bird Spikes

Bird spikes are considered one of the most simple and effective strategies for preventing bird nesting. They work by installing dull metal spikes at desired rooftop locations, typically along the edges of solar modules, or on the edges of rooftops. These spikes are not sharp and do not harm the birds in any way, but simply obstruct them from landing and resting in the installed locations. Bird spikes are versatile in their application and can be tailored to fit in many different configurations. They are a great option due to their simplistic design, ease of installation, and limited maintenance requirements. These factors also contribute to their low cost compared to other mitigation strategies.

9.5.1.3 Acoustic Deterrent System

Acoustic sound deterrents are another effective strategy to prevent bird settling. For this method, a loudspeaker is installed onto rooftops, and programmed to play a predator bird's calling. This bird call is automated to repeat after certain period of time, typically anywhere between 1 and 10 minutes. The selected predator call can be tailored to the area's natural habitat to ensure it is deterring the right species of birds.

Acoustic bird deterrents are another option that are come at a low price and require little to no maintenance. This is a strategy that Jacobs has used and proven to be effective on other previous solar projects.

9.5.1.4 Cleaning Systems

Dust and debris buildup on solar modules causes shading and can have a significant negative impact on the overall system performance. Because of this, regularly scheduled cleaning is requirement of any solar system, however it becomes even more important in locations with high bird traffic due to their droppings on solar modules. Solar modules can be cleaned off manually, or alternatively an automated cleaning system can be installed.

Automated systems can come in a few different forms. The most common method is an automated sprinkler system that sprays water to rinse off solar modules. Another technique is dry cleaning which consists of mechanical brush systems that wipe dust off solar modules, similar to wind shield wipers on a car.

It is recommended for the Port that a combination of acoustic, laser, and automatic sprinkler washing systems be implemented and tested to ensure functional solar PV system on Warehouse A. Acoustic measure should be tested on the local seabird population prior to final installation to ensure the correct alignment of predator sounds, as well as the timing at which the sounds need to be rotated.

9.6 Solar Photovoltaic Maintenance

Developing an operation and maintenance contract with a solar rooftop operation and maintenance contractor is strongly advisable. This might be the same contractor that designs and installs the solar on the roof, or it might be a separate contractor. Contractors bidding on an operation and maintenance contract will evaluate the regional conditions and make recommendations about if services are warranted and how often. An example service that may or may not be warranted is module cleaning. In some regions, rainfall is high enough to provide regular module cleaning. Some regions, such as dry/ dusty or coastal areas, will have enough airborne sediments or salt buildup on modules and components to warrant regular manual cleaning. An example service that should not be optional is periodic wire and inverter inspection. Though components, such as wiring and connectors, are designed to be exposed to the sun, they will degrade over time. Inspecting these components regularly is key to maintaining a well-functioning safe installation.

9.7 Available Solar Incentives

The IRA was signed into law on August 16, 2022, and provides substantial funding for solar systems, and eligible reflective roofing systems, procurement and installation via an ITC. The IRA increased the ITC to 30 percent; plus bonuses for projects with domestic content, qualified energy communities, and low income areas, applicable until 2033. Figure 9-14 shows the credit breakdown and how it decreases over time to 2036. A Direct Pay Option enables non-profits to receive a cash payment in lieu of the ITC. If the Port is not eligible for the direct pay option due to the Port's tax status a tax credit transferability could enable a one-time tax-free sale of the ITC to an unrelated third party where the depreciation retained by system owner. The solar PV system located at Warehouse A would be eligible for likely an ITC credit of 40 percent, combining the Base 30 percent plus additional 10 percent for low income areas (Figure 9-15). The IRA provisions for the ITC are further illustrated as follows, and on Figure 9-14.

<u>IRA provisions for full 30 percent ITC:</u>
① <1 MWac system size OR
② Meet prevailing wage AND apprenticeship requirements
✓Project *qualifies* under #2

<u>IRA provisions for bonus 10 percent ITC for domestic content</u>:
① 100 percent US steel in project and
② Minimum 40 percent of equipment cost from US manufacturers
✓Project meets #1 via current suppliers of racking
✓Need to evaluate options on equipment to meet #2; *unlikely* in 2023 given limited U.S. suppliers, but anticipated that this supply will increase and be available by 2025.

<u>IRA "bonus" language includes additional 10 percent tax credits for:</u>
① Qualified energy communities OR
② Low income areas
✓Dependent on project location; project *likely to qualify* for #2 based on expected Treasury guidance

Figure 9-14. Summary of ITC and PTC Values over Time

Source: U.S. Department of Energy (https://www.energy.gov/eere/solar/federal-solar-tax-credits-businesses)

Summary of Investment Tax Credit (ITC) and Production Tax Credit (PTC) Values Over Time

			Start of Construction						
			2006 to 2019	2020 to 2021	2022	2023 to 2033	The later of 2034 (or two years after applicable year[a])	The later of 2035 (or three years after applicable year[a])	The later of 2036 (or four years after applicable year[a])
ITC	Full rate (if project meets labor requirements[b])	Base Credit	30%	26%	30%	30%	22.5%	15%	0%
ITC	Full rate (if project meets labor requirements[b])	Domestic Content Bonus				10%	7.5%	5%	0%
ITC	Full rate (if project meets labor requirements[b])	Energy Community Bonus				10%	7.5%	5%	0%
ITC	Base rate (if project does not meet labor requirements[b])	Base Credit	30%	26%	6%	6%	4.5%	3%	0%
ITC	Base rate (if project does not meet labor requirements[b])	Domestic Content Bonus				2%	1.5%	1%	0%
ITC	Base rate (if project does not meet labor requirements[b])	Energy Community Bonus				2%	1.5%	1%	0%
ITC	Low-income bonus (1.8 GW/yr cap)	<5 MW projects in LMI communities or Indian land				10%	10%	10%	10%
ITC	Low-income bonus (1.8 GW/yr cap)	Qualified low-income residential building project / Qualified low-income economic benefit project				20%	20%	20%	20%
PTC for 10 years ($2022)	Full rate (if project meets labor requirements[b])	Base Credit			2.75 ¢	2.75 ¢	2.0 ¢	1.3 ¢	0.0 ¢
PTC for 10 years ($2022)	Full rate (if project meets labor requirements[b])	Domestic Content Bonus				0.3 ¢	0.2 ¢	0.1 ¢	0.0 ¢
PTC for 10 years ($2022)	Full rate (if project meets labor requirements[b])	Energy Community Bonus				0.3 ¢	0.2 ¢	0.1 ¢	0.0 ¢
PTC for 10 years ($2022)	Base rate (if project does not meet labor requirements[b])	Base Credit			0.55 ¢	0.55 ¢	0.4 ¢	0.3 ¢	0.0 ¢
PTC for 10 years ($2022)	Base rate (if project does not meet labor requirements[b])	Domestic Content Bonus				0.1 ¢	0.0 ¢	0.0 ¢	0.0 ¢
PTC for 10 years ($2022)	Base rate (if project does not meet labor requirements[b])	Energy Community Bonus				0.1 ¢	0.0 ¢	0.1 ¢	0.0 ¢

a "Applicable year" is defined as the later of (i) 2032 or (ii) the year the Treasury Secretary determines that there has been a 75% or more reduction in annual greenhouse gas emissions from the production of electricity in the United States as compared to the calendar year 2022.

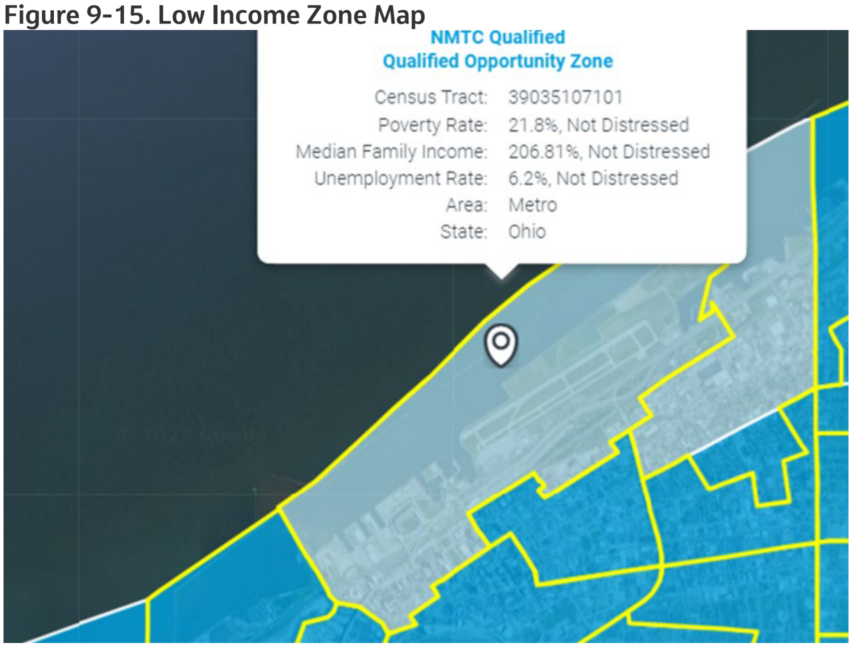
b "Labor requirements" entail certain prevailing wage and apprenticeship conditions being met.

As noted above the federal government provides the following options and direction for organizations that do not pay federal taxes, like non-profits or local governments, on how to take advantage of the tax credits through either direct pay or a transfer of credit.

- Direct pay option: "Tax-exempt organizations (i.e. non-profits), states, municipalities, the Tennessee Valley Authority, Indian Tribal governments, any Alaskan Native Corporation, and any rural electric cooperative can receive a refund from the IRS for tax credits on projects placed in service after 2022. Projects starting construction in 2024 and 1 MW or above must meet domestic content requirements or may only receive a refund of 90 percent of the tax credit. This percentage lowers to 85 percent for projects starting construction in 2025 and 0 percent for projects starting construction after 2025. A penalty of 20 percent may apply where excess payments are requested and made by the IRS. Individuals and for-profit corporations eligible for the ITC and PTC may only use them against federal taxes owed in a given year and therefore the credits are not refundable (though they may be rolled forward)" (Office of Energy Efficiency and Renewable Energy 2023).

- Transfer of credit: "Eligible taxpayers who are not eligible for direct payment, may sell all, or a portion, of the tax credits for a given year to an unrelated eligible taxpayer. Payments for the credit must be made in cash and are not considered gross income, for federal purposes (i.e. no federal taxes are owed on receiving the payment and no deduction is available to the tax credit buyer for making the payment). A penalty of 20 percent may apply where excess credits are claimed" (Office of Energy Efficiency and Renewable Energy 2023).

Figure 9-15. Low Income Zone Map



9.8 Power Purchase Agreements

A PPA can enable a third party developer to cover the entire installation and operations costs of the system, with the Port only responsible for purchasing the power generated by the solar system providing a hedge for a significant portion of the electricity needs of the facility

The Port would be committing to purchasing the power generated by the solar array, with an energy production guarantee, typically guaranteeing 85 percent of the expected annual energy production. This will allow the Port to have known power costs for a significant portion of the energy needs for the next 25 years.

In general the PPA approach is designed to be treated as an energy contract vs. a traditional lease or debt capacity instrument. In particular, the PPAs are off balance sheet transactions. PPAs (which have an operational component that falls on the special purpose entity, etc.) are not treated as a balance sheet obligation.

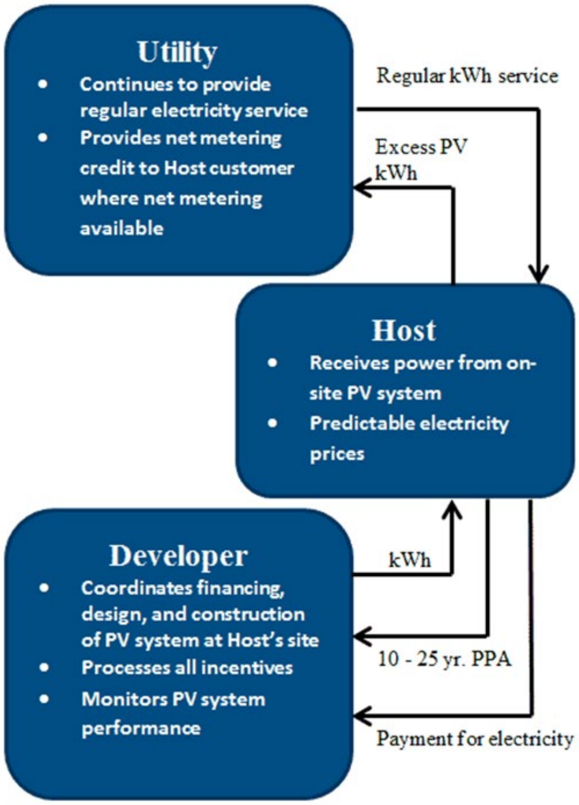
In summary a PPA structure could enable the following:

- Developer/investor pays all installation costs for the system, including roofing costs
- Host facility provides the site (rooftop, ground, etc.)

- Host facility purchases the power generated by the solar system at the rate specified in the PPA
- Developer/investor covers all operations (including operating costs)

The partially prepaid PPA structure (Figure 9-16) is a mechanism that preserves the tax credit treatment for the project investor while enabling the energy user to “buy down” the PPA rate. For example, Port could partially prepay to have a net PPA rate that is equal to or less than the current electricity costs. Appendix L further details the capital costs, payback periods, and potential financial model if a PPA was used by the Port to help finance the costs of the solar on the three warehouses.

Figure 9-16. PPA Energy Transaction Structure Example



9.9 Summary

In total a combined Warehouse A, Warehouse 24, and Warehouse 26 solar PV system would generate an estimated 4.8 GWh of energy per year depending on the selected PV racking system. As discussed in Section 6, the development of onsite power generation is a critical element of what is necessary to significantly reduce the port's emissions profile.

Phasing for implementation will be influenced by the following elements: coordination with CPP on net metered service interconnection location and timeline; environmental impact planning for solar and wind turbine systems; funding availability for the capital construction and equipment procurement; as well as traditional design/build project timelines. It is recommended that the initial CPP coordination and siting for the solar PV occur early in the overall project, ideally where the onsite generation infrastructure is commissioned and operating prior to deployment of battery electric equipment and cold ironing.

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Appendix A
Global Port and Maritime Growth Trends

A. Global Port and Maritime Growth Trends

Global trade patterns have a significant impact on shipping and breakbulk cargo industries. The rise of China and India's emerging economies has led to increased trade volumes, while changes in global manufacturing and sourcing strategies have affected cargo flows. The ongoing shifts in trade routes and the emergence of new trade corridors, such as the Belt and Road Initiative, influence demand for shipping and breakbulk cargo services (United Nations Conference on Trade and Development [UNCTAD] 2021).

Additionally, technological advancements are transforming the shipping and breakbulk cargo industries. Digitization, automation, and the Internet of Things enable improved supply chain visibility, streamlined operations, and enhanced efficiency. Technologies like blockchain hold promise for secure and transparent documentation and traceability (UNCTAD 2021). The adoption of autonomous vessels and drones for cargo handling and inspection is also gaining traction (Harms 2021).

As in many sectors, regulatory changes and initiatives also influence the shipping and breakbulk cargo industries. Environmental regulations such as the International Maritime Organization's (IMO's) sulfur emissions limit, which went into effect January 2023, and the push for decarbonization drive the adoption of cleaner fuels and the development of alternative propulsion systems in the industry. Regulations related to safety, security, and labor standards simultaneously impact industry practices (UNCTAD 2021). Complying with these regulations is required while two key trends in the breakbulk market are anticipated to continue in 2023. These include the push toward energy security and decarbonization driving investment in renewables and electric vehicles (EVs), and supply shortages in the construction equipment market leading to higher prices (Hargreaves 2022).

Lastly, sustainability has become central for the shipping and breakbulk cargo industries. Stakeholders are increasingly focused on reducing greenhouse gas emissions, improving energy efficiency, and implementing eco-friendly practices. Initiatives like the IMO's Energy Efficiency Design Index and the International Chamber of Shipping's (ICS') decarbonization roadmap guide industry efforts toward a more sustainable future (ICS 2021).

It is evident these trends are leading to increased maritime investment in green energy. In fact, the transition to clean energy led to an 8% increase in renewables capacity in 2022 (Hargreaves 2022). This growth is expected to remain steady in the coming years. A momentum in the green energy transition is toward a hydrogen economy, which is creating an opportunity for ports to play a pivotal role in enabling the movement of hydrogen feedstocks. Because of their strategic locations, existing infrastructure, and shipping networks, ports have the potential to serve as crucial hubs for the transportation, storage, and distribution of hydrogen. Specifically, ports can contribute to the hydrogen economy through infrastructure development, integration with existing shipping networks, and collaboration with industry stakeholders.

Ports can invest in infrastructure development tailored to handle hydrogen feedstocks. This includes the construction of specialized hydrogen terminals or hubs equipped with facilities for hydrogen production, storage, and loading onto ships or other transport modes. This infrastructure can accommodate different forms of hydrogen, such as compressed hydrogen, liquid hydrogen, or hydrogen carriers like ammonia.

Additionally, ports are ideal importers and exporters of hydrogen feedstocks. Ports can leverage existing shipping routes and vessels to transport hydrogen, either in its pure form or as hydrogen carriers. Integration with the maritime shipping industry allows for efficient and cost-effective transport of hydrogen over long distances, enabling access to a broader market (Maritime Executive 2021).

As with any new technology, collaboration is essential for the successful integration of hydrogen feedstock transport. Ports can engage with hydrogen producers, suppliers, and users to develop standardized protocols, safety guidelines, and regulations for hydrogen handling, storage, and transportation. Such collaboration can foster the creation of a robust and reliable hydrogen supply chain (Erickson 2021).

Furthermore, ports could initiate pilot projects and demonstrations to showcase the viability of hydrogen feedstock transport. These initiatives could involve retrofitting vessels for hydrogen propulsion, testing new hydrogen storage and loading technologies, and exploring innovative solutions for onshore and offshore hydrogen infrastructure. Pilot projects provide valuable insights and contribute to the collective learning in the emerging hydrogen industry (Feng et al. 2020).

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Appendix B
Factors Affecting Energy Efficiency During Cold Weather

B. Factors Affecting Energy Efficiency During Cold Weather

The energy efficiency of electric vehicles (EVs) is influenced by several key variables, each playing a significant role in determining the EV's range and overall performance. Perhaps the most crucial factor is ambient temperature, which affects power demand from the EV’s heating, ventilation and air conditioning (HVAC) system and defroster. Running an EV’s HVAC and defroster can put a strain on the battery, especially in extreme weather conditions. In cold weather, heating an EV's cabin and using the defroster can lead to a substantial reduction in the EV's range, while in hot weather, using air conditioning can also impact efficiency. Pre-conditioning when the vehicle is plugged in can help to minimize the impact on range by conditioning the cabin while connected to a power source. The effects of HVAC in cold weather on the efficiency of fuel-cell electric vehicles (FCEVs) are typically less drastic than pure battery electric vehicles (BEVs), as the fuel cell provides waste heat that can be repurposed for cabin heat or battery thermal management.

Battery thermal conditioning is another essential variable in an EV’s range. Maintaining a battery at an optimal temperature range is vital for its performance and longevity. Extreme temperatures can negatively affect a battery’s efficiency. Modern EVs are equipped with advanced thermal management systems to regulate battery temperature, ensuring their stability and performance over the long term. As fuel cell electric cargo handling equipment (FCECHE) has smaller battery packs and can use waste heat from the fuel cell, it is expected the energy demand for battery thermal conditioning will be less than the battery electric counterparts.

The duty cycle of an EV battery encompasses various aspects such as speed, terrain, and grades encountered during operation. Driving at higher speeds increases air resistance, requiring more energy to overcome it, thereby decreasing an EV's range. Hilly terrain and steep grades demand more power from an EV battery, further impacting energy efficiency. However, regenerative braking can help recapture some energy during downhill driving and deceleration. Efficient driving strategies, such as maintaining a steady speed and using regenerative braking settings wisely, can optimize energy consumption and improve an EV's range.

Driver behavior is a variable that can significantly influence the energy efficiency of an EV battery. Aggressive driving habits, such as rapid acceleration and hard braking, can lead to a considerable reduction in energy recovered through regenerative braking. Using regenerative braking effectively can further improve efficiency.

Lastly, auxiliary loads, which encompass 12-volt (V)/24V accessories, power steering, compressed air systems, and other electrical components, contribute to a more stable but constant energy demand. Although the impact of each individual load might be relatively small, their cumulative effect can affect overall energy efficiency. Duty cycle, driver behavior, and auxiliary loads will typically affect the batteries of BEVs similarly to FCEVs.

Appendix C
Fleet Energy Analysis and Methodology

C. Fleet Energy Analysis and Methodology

This master plan aimed to create grounded and realistic energy usage assumptions that were based upon real world fuel usage of the current cargo handling fleet. This section overviews the methodology of how data were collected, analyzed, and ultimately provided assumptions on how best to size a future battery electric cargo handling equipment's battery sizes, along with available commercial equivalents on the market today.

C.1 Asset Classification

The first step in determining the proper zero-emission equivalent for each vehicle and piece of equipment in the Port of Cleveland's (Port's) fleet was ensuring each asset was properly classified. For this project, each asset was classified by type, weight class (or forklift class or lifting capacity), and its anticipated useful life span. These classifications informed the replacement timeline and difficulty of electrification analysis. The following sections describe the assumptions and application of each of these classifications.

C.2 Weight Class, Forklift Class, and Lifting Capacity

The Port has a mixed fleet that includes on- and off-road vehicles. A significant portion of the fleet are forklifts and other cargo-handling equipment. , Port forklifts and reach stackers were each be assigned a class, ranging from 1 to 7, as defined by the federal Occupational Safety and Health Administration (OSHA) forklift classifications (OSHA Powered Industrial Trucks https://www.osha.gov/etools/powered-industrial-trucks/types-fundamentals/types/classes ,2023).

Additionally, all cargo-handling equipment such as forklifts, reach stackers, and mobile harbor cranes were assigned a lifting capacity rating as defined by the original equipment manufacturer (OEM). To determine each of these classifications, the manufacturer, model, and vehicle year were taken from the information provided by the Port for analysis. Clearly defining classifications for each asset in the Port's fleet, helped to evaluate applicable zero-emission equivalents and a level of difficulty for electrification. Criteria for classification are described below.

C.2.1. Vehicle Type

Vehicle type is a quick description of a vehicle's form and function. Standard vehicle types include sport utility vehicle (SUV), van, sedan, pickup truck, straight truck, semi-trailer truck, and similar. The majority of the Port's assets are classified as one of these standard vehicle types; however, because the Port operates many specialty vehicles, some more descriptive vehicle types were needed for non-standard vehicles. Some non-standard vehicle examples include street sweeper, skid steer, stinger truck, aerial lift, tractor truck, crane truck, and similar. These vehicle type classifications were useful when advising on the availability of EV equivalents in the market, especially when combined with a vehicle's weight classification.

C.2.2. Useful Life Span

Jacobs worked with the Port to create clear definitions (Table C-1) of an asset's useful life span based on asset type and weight classification. An asset's useful life span was used to determine when the Port will need to make a capital investment and procure a zero-emission equivalent.

Table C-1. Parameters for Vehicle Replacement

Equipment Type	Useful Life Span
Mobile Harbor Crane	20 years
Reach Stacker	10 years or 10,000 hours
Pickups and Light-Duty Basic	10 years or 100,000 miles

Equipment Type	Useful Life Span
Heavy Duty Trucks (over 26,000 pounds.) (Yard Tractors)	12 years or 100,000 miles
Heavy Duty Equipment and Construction Equipment (Payloader)	15 years or 10,000 hours
Portable Generators	20 years or 5,000 hours
Small Off-Road and Other Equipment (UTVs and manlifts)	12 years
Forklifts	10 years or 10,000 hours
Work Barges	25 years (Hull) & 10 years (Powertrain)

C.3 Difficulty of Electrification

The EV market is growing quickly, with new options available every quarter; however, much of the focus from OEMs has been on class 1 and 2 consumer EVs. Options for class 3 through 8 EVs are slowly starting to come to market, but for most class 3 through 8 vehicles, EV equivalents are not readily available. For the purposes of this analysis, it was useful to classify vehicles on ease of electrification based on the current market landscape. Additionally, for agencies like the Port that use federal and state funds, other factors such as compliance with the Federal Transit Authority's Buy America requirements and availability on federal and state procurement contracts are important. To assess the difficulty of electrification more easily for each vehicle class and equipment type, a scale from 1 to 5 was defined (Figure C-1).

Figure C-1. Electrification Level of Difficulty Definitions

1—Commercially Available Today	2—Near-term Commercial Availability	3—Limited Availability in the Next 5 Years	4—Possib e Commercial Availablity in 5 Years	5—No Planned Commerical Availability
Many commercial options exist from multip e OEMs at competitive prices. Vehicles can be found on federal General Services Adminstration and state procurement contracts Specifications, reliability, and performance well understood.	Options are more limited, but models are currently commercially available Vehic es can be found on federal General Services Adminstration and state procurement contracts OEMs have plans to release new models in the near term. Specifications, reliability, and performance relatively well understood.	While some models may exist, they are in the early stages of being produced resulting in limited availability. Specification, performance, and reliability scarcely known.	No models currently exist for purchase, but OEMs have announced plans to produce an EV variant in near to mid-term. Specification, performance, and reliability mostly unknown.	No models currently exist, and OEMs have not announced plans to produce an EV variant in the near to mid-term.

C.4 Methodology

To determine the Port fleet's energy demand, excluding SUVs and light-duty pickup trucks, the average fuel consumption in gallons per hour (g/hr) was determined. A separate methodology was used to determine fuel consumption for the Port's light-duty on-road fleet, which consists of SUVs and pickup trucks (refer to Section C.4.1). Because the Port's 2022 operating hours are known for each asset in the fleet, determining average fuel consumption on a per hour basis allowed a straightforward calculation of annual energy demand for each asset. Additionally, the Port provided assumptions regarding maximum daily operating hours, which were used in combination with average fuel consumption to predict maximum daily energy demand per asset. However, because the Port has limited empirical data about fuel consumption, a methodology was needed to estimate each asset's unique average fuel consumption. Industry standard practice was used to estimate fuel consumption based on brake-specific fuel consumption (BSFC), load factor, and rated engine power.

BSFC is measured in grams per kilowatt hour (g/kWh) of fuel mass consumed per unit of time and unit of power when an engine is operating its rated power. BSFC is typically calculated using the following equation:

Equation C-1. BSFC Equation

$$grams\ of\ fuel\ per\ kiloWatt * hour\ or\ g/kWh$$

In the equation, the value is dependent on engine type, size, and design. The lower the value, the less fuel by weight is consumed per unit of power and unit of time, meaning the engine is more efficient at converting fuel into useful work. For diesel engines, the BSFC ranges from 200 to 260 g/kWh with the lower values corresponding to modern and low-hour engines and the higher values corresponding to older, less-advanced, or worn-out engines (Klanfar et al. 2016). Additionally, BSFC also varies with engine size and power output, with larger and more powerful engines typically having a lower BSFC.

An engine's load factor describes the average proportion of rated power used. The value is specific to the equipment type and application but is independent of an asset's size and rated engine power. To calculate fuel consumption, the load factor must be averaged over an asset's work cycle or longer period of operation. A load factor can be calculated from empirical data obtained by measuring a vehicle's fuel consumption over time, and comparing to the fuel consumption of the vehicle's engine at full load. Load factors calculated from empirical data can be applied to assets of the same type and application/ operating conditions but with different sizes and engine powers. When empirical data are not available, as is the case for many of the asset types in the Port's fleet, the US Environmental Protection Agency (EPA) and the California Air Resources Board (CARB) have recommended load factors that are informed by meta-analysis of equipment and vehicle operations in the United States.

Rated engine power is the peak power of an engine at a specified rotations per minute (rpm). The Port provided rated engine power for each asset in their fleet. Those values were checked against the asset's model and were changed where needed. When these values are known, the following equation can be used to determine average fuel consumption.

Equation C-2. Fuel Consumption Equation

$$P * lf * BSFC = fc_a$$

Where

P = rated engine power in kW
lf = engine load factor
$BSFC$ = break-specific fuel consumption in g/kWh
fc_a = average fuel consumption in g/hr

Once average fuel consumption is calculated in g/hr, it can then be converted to gallons per hour by dividing by the density in grams per gallon (g/gal) of fuel used by the engine being analyzed. Once the average fuel consumption is estimated, the maximum daily energy demand and annual energy demand can be determined using the following equation.

Equation C-3. Energy Demand Equation

$$fc_a * fge * \eta * oh = e_d$$

Where

fge = fuel gallon energy in kWh/gal
η = thermal efficiency in percent
oh = operating hours
e_d = energy demand in kWh

Equation C-3 can be used to calculate both the annual and maximum daily energy demand by changing the value used for operating hours.

C.4.1. On-road Fleet Methodology

In addition to the Port's heavy duty trucks, cargo-handling equipment, work barges and other off-road equipment, the Port has a fleet of light-duty on-road SUVs and pickup trucks. The EPA has an established testing methodology to determine light-duty on-road vehicle efficiency reported as miles per gallon of gasoline-equivalent (MPGe). MPGe is the measure of the average distance traveled per unit of energy consumed. As such, if the peak daily and annual mileage is known the following equation can be used to estimate the peak daily and annual energy demand of the recommended EV equivalent.

Equation C-4. Energy Demand Analysis

$$mi * \frac{fge}{MPG_e} = e_d$$

Where

mi = miles traveled in miles
fge = fuel gallon energy in kWh/gal
MPGe = the EPA combined MGPe for vehicle of interest
e_d = energy demand in kWh

C.4.1.1. Assumptions

The following are the key assumptions for the energy demand model:

- Diesel fuel is assumed to weigh 7.1 pounds per gallon.
- To determine the maximum daily energy requirement, it is assumed the vehicle is operating for 8 hours in a day with no charging breaks. This assumption was informed by the Port's operating schedule.
- BSFC is assumed to be 220 g/kWh for all diesel-powered assets. While each engine will have a unique BSFC based on its design and size, 220 g/kWh is an industry accepted assumption for small- to medium-sized modern diesel engines, and is used by EPA and CARB for their emissions and energy modeling.
- Diesel engine thermal efficiency of 43% was assumed. This thermal efficiency comes from testing conducted by EPA on non-road diesel engines from seven different manufacturers with displacements ranging from.2 to 34.5 liters (Nam et al. 2005).
- Energy content of 37.64 kWh per diesel gallon was assumed. This energy content comes from the US Department of Energy's Alternative Fuel Data Centers value for lower heating value for low-sulfur diesel (Argonne National Laboratory 2019). Energy content of 33.7 kWh per gallon was assumed for gasoline per the EPA.
- Asset type load factors were determined, when possible, from empirical data sourced from the Port's fueling records or from Cummins ECU fuel consumption data. For all load factors calculated from empirical data, an error margin of 10% was applied. For asset types in which empirical data was not available, load factors from CARB's report on 2022 Cargo-Handling Equipment Emissions were used (CARB 2023). For all other equipment types, load factors from the EPA were used (EPA 2010). Load factors for each equipment type are detailed in Table C-2.

Table C-2. Load Factors By Equipment Type

Equipment Type	Load Factor	Load Factor Source
Forklift	.16	Empirical data—Cummins
Reach Stacker	.33	Empirical data—Port's fueling records
Mobile Harbor Crane	.25	Empirical data—Port's fueling records
Man Lift	.31	CARB

Equipment Type	Load Factor	Load Factor Source
Utility Task Vehicle	.42	CARB
Work Barge	.35	EPA
Generator	.43	EPA
Yard Tractor	.51	CARB
Payloader	.55	CARB

C.4.1.2. Results

[Based on the assumptions above, the data collected onsite at the Port, as well as the utilized load factor data, Jacobs was able to produce usable results to inform future electric cargo handling equipment specifications. In Table C-3 the results are overviewed showing the current asset and its weight rating, along with maximum daily energy demand, as well as an averaged yearly demand that has been adjusted to the 2022 operating hours data provided by the Port.

The Port's list of cargo-handling equipment includes mobile harbor cranes, light-duty pickup trucks and SUVs, a switching locomotive, reach stackers, yard tractors, payloaders, and a variety of forklifts ranging from 15,500-pound to 62,000-pound ratings.

Table C-3 also shows utility terrain vehicles, work barges, mobile generators, and man lifts, which are currently diesel-powered and should also be converted to zero-emission battery electric equivalents as part of this master planning effort.

Table C-3. Energy Usage of Assets

Asset Type	Engine Rating (horsepower)	Manufacturer	Maximum Lift Rating (pounds)	Load Factor	2022 Asset Usage (hours)	Average Fuel Consumption (g/hr)	Maximum Daily Energy Demand (kWh)	Yearly Energy Demands (kWh)
Forklift	252	Kalmar	55,000	0.16	57	2.1	266	1,895
Forklift	252	Kalmar	55,000	0.16	883	2.1	266	29,354
Forklift	155	Yale	36,000	0.16	695	1.3	164	14,211
Forklift	168	Hyster	28,000	0.16	590	1.4	177	13,076
Forklift	168	Hyster	28,000	0.16	137	1.4	177	3,036
Forklift	74	Hyster	5,500	0.16	109	0.6	78	1,064
Forklift	105	Yale	15,500	0.16	650	0.9	111	9,003
Forklift	105	Yale	15,500	0.16	733	0.9	111	10,153
Forklift	168	Hyster	36,000	0.16	1,288	1.4	177	28,545
Forklift	168	Hyster	36,000	0.16	1,108	1.4	177	24,556
Forklift	168	Hyster	36,000	0.16	981	1.4	177	21,741
Forklift	270	Hyster	55,000	0.16	997	2.2	285	35,511
Forklift	270	Hyster	55,000	0.16	30	2.2	285	1,069
Forklift	270	Hyster	55,000	0.16	302	2.2	285	10,757
Forklift	270	Hyster	62,000	0.16	567	2.2	285	20,195
Forklift	270	Hyster	70,000	0.16	411	2.2	285	14,639
Forklift	250	Taylor	52,000	0.16	263	2.0	264	8,674
Forklift	215	Taylor	35,000	0.16	1,019	1.8	227	28,901
Forklift	240	Taylor	55,000	0.16	705	2.0	253	22,320
Forklift	240	Taylor	55,000	0.16	565	2.0	253	17,888
Forklift	173	Taylor	36,000	0.16	141	1.4	183	3,218
Generator	20	Kubota	NA	0.43	46	0.4	57	326
Man Lift	65	Snorkel	500	0.31	150	1.0	133	2,492
Man Lift	65	Snorkel	500	0.31	150	1.0	133	2,492

Asset Type	Engine Rating (horsepower)	Manufacturer	Maximum Lift Rating (pounds)	Load Factor	2022 Asset Usage (hours)	Average Fuel Consumption (g/hr)	Maximum Daily Energy Demand (kWh)	Yearly Energy Demands (kWh)
Mobile Crane	536	Leibherr	185,000	0.25	1,313.93	6.8	884	145,164
Mobile Crane	536	Leibherr	185,000	0.25	1,051.61	6.8	884	116,183
Payloader	330	Volvo	41,000	0.55	28	9.2	1,197	4,190
Reach Stacker	365	Hyster	99,200	0.33	893	6.1	794	88,683
Reach Stacker	365	Hyster	99,200	0.33	1,033	6.1	794	102,586
UTV	58	Bobcat	NA	0.42	185	1.2	161	3,716
UTV	24	Polaris	NA	0.42	300	0.5	66	2,493
Work Barge	225	Lake Assault	NA	0.35	920	4.0	519	59,734
Work Barge	225		NA	0.35	920	4.0	519	59,734
Yard Tractor	200	Ottawa	NA	0.51	100	5.2	673	8,410
Yard Tractor	225	Capacity	NA	0.51	12	5.8	757	1,135
Yard Tractor	225	Capacity	NA	0.51	33	5.8	757	3,122

C.5 References

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Appendix D
Industry Trends and Electric Vehicle Equivalent Selection

D. Industry Trends and Electric Vehicle Equivalent Selection

In the past decade battery electric and hydrogen as primary propulsion fuels for port cargo handling equipment have grown from niche impractical technologies to mainstream products readily offered by top manufacturers. Battery electric truck products on the market currently range from smaller UTVs and support equipment to heavy duty 70,000 pound forklifts and container handlers, along with a variety of vocational truck types in between.

D.1 Cargo-Handling Equipment

Cargo-handling equipment are candidates for electrification because they typically operate indoors, require a heavy counterweight for which a battery can be used, have predictable duty cycles and operate within a set boundary. The industry has recognized this for some time, resulting in approximately 60% of North American annual forklift sales volume being electric since 2001. This percentage significantly surpasses any other vehicle type. In comparison, only 6% of North American passenger vehicle sales were electric in 2022.

At present, battery electric forklifts dominate the market. However, hydrogen fuel-cell-powered forklifts have seen steady sales growth, with over 50,000 units in service in North America as of 2022, according to the US Department of Energy. The majority of hydrogen fuel cell and battery electric forklift sales have been of federal Occupational Safety and Health Administration (OSHA) class 1 and 2 forklifts, designed primarily for indoor operation with limited load capacities. Additionally, most battery powered electric forklifts deployed in North America use lead-acid batteries, with lithium-ion batteries becoming a recent option.

As described in Appendix C, all the Port's cargo-handling equipment are OSHA class 5 forklifts. Historically, class 5 forklifts have relied on internal combustion engines (ICEs) to meet high torque and power demands necessary for handling heavy loads and operating in rough outdoor terrains. Class 5 forklifts are commonly employed in intensive applications such as construction sites, lumber and timber operations, ports and shipping yards, and agriculture settings. However, with advancements in zero-emission technology and increasing government regulation and funding, the following key factors have emerged, making it technologically feasible and financially viable to electrify class 5 forklifts.

- **Improvement in Battery Technology**: In the past, most battery electric forklifts sold in North America were equipped with lead-acid batteries due to their availability and low cost. However, lead-acid batteries have limitations in terms of their energy density and performance, making them impractical for class 5 forklifts. Recent developments in lithium-based battery technology have resulted in increased performance and energy density, coupled with a decrease in costs per kilowatt hour (kWh). Per a report from the US Department of Energy, lithium-ion battery prices per kWh have reduced by 90% since 2008. Improvements in lithium-based battery technology plus a large reduction in price per kWh have now made it feasible to electrify class 5 forklifts, either through fuel cell or full battery electric solutions.
- **Advancements in Charging and Hydrogen Fueling Infrastructure:** In recent years, there have been significant improvements in both hydrogen fueling and EVs charging infrastructure. These advancements have been made possible by the standardization of fueling and charging hardware, as well as communication and safety protocols, largely driven by the efforts of standards organizations such as the Charging Interface Initiative (CHArIN). Today, direct current fast chargers (DCFCs) are available from a growing list of manufacturers, with many DCFCs being able to reach power outputs in excess of 350 kilowatts (kW). This allows modern battery electric vehicles (BEVs) equipped with standardized DCFC ports to replenish their batteries in tens of minutes rather than hours.
- **Governmental Regulation and Funding**: Recent governmental regulations and funding have been crucial in creating a supportive environment for zero-emission vehicle adoption. Today, zero-emission vehicles are still substantially more expensive to purchase than their ICE-powered equivalents. To help

spur zero-emission vehicle adoption, state and federal governments have created programs that provide tax and/or cash incentives for zero-emission vehicles and associated charging and fueling infrastructure projects, or grants that can help partially or fully fund zero-emission vehicle and charging/fueling infrastructure projects. In Ohio, the Ohio Environmental Protection Agency has allocated funds from the Volkswagen Clean Air Act settlement for grants to help fund the procurement of heavy duty on and off-road vehicles, such as port cargo-handling equipment. Federally, the US government has allocated $3 billion in the 2022 Inflation Reduction Act to fund zero-emission port equipment and technology. These programs, coupled with growing regulations on emissions from ICE vehicles, are expected to boost zero-emission vehicle adoption and eventually drive down unit prices. The ultimate goal is to achieve price parity between zero-emission and ICE vehicles, making cleaner transportation options more accessible and appealing to consumers.

While both battery electric and hydrogen fuel-cell technologies have made significant advancements in recent years, original equipment manufacturers (OEMs) have shown a preference for full battery electric systems when it comes to class 5 forklifts. Prominent manufacturers such as Kalmar, Hyster, and Taylor have each introduced lines of battery electric class 5 forklifts, targeting heavy duty applications.

Numerous test deployments have been carried out using battery electric class 5 forklifts. Taylor has conducted demonstration deployments at major ports such as Port of Los Angeles, Port of Long Beach, and Port of Oakland over the past 3 years, showcasing both their ZLC-900 series battery electric reach stackers and ZH-360L heavy duty battery electric forklift. Per a report shared with Jacobs from the City of Los Angeles Harbor Department (City of Los Angeles Harbor Department, Everport Advanced Cargo Handling Demonstration Project, April 2021), two Taylor ZLC-976 reach stackers recorded a cumulative 2,512 hours of operation between April 1, 2020 and March 31, 2021. During that time, no major issues were reported by the Los Angeles Harbor Department. Similarly, Kalmar has been actively deploying their heavy duty electric forklifts across various locations in Europe since 2021, with units serving daily operations at 11 concrete manufacturing sites owned by SEAC in France. As orders and deployments of battery electric class 5 forklifts become more commonplace, many of the deployments are no longer publicized, signifying the growing adoption and integration of heavy duty electric forklifts in various industrial settings.

Hydrogen fuel-cell class 5 forklifts are in an early phase of development, with only a few manufacturers publicly announcing their involvement in the development and test deployment phases for such technology. As of now, Hyster and Wiggins are the manufacturers that have made public announcements regarding their hydrogen fuel-cell powered class 5 forklift initiatives. Wiggins has stated that they plan to deliver their first fuel-cell powered forklift by the end of 2023. While Hyster has already deployed fuel-cell powered reach stackers at the Port of Los Angeles since 2022 and at the Port of Valencia in Spain since 2021. While it is possible that other heavy duty cargo-handling equipment manufacturers are working on fuel-cell-powered equipment, no public announcements have been made by them at this time. This indicates that the adoption of hydrogen fuel-cell technology for class 5 forklifts is currently limited and still in the early stages of research and development.

The determination that battery electric technology for class 5 heavy duty forklifts is more mature than hydrogen fuel-cell technology was also reached by a study undertaken by Ports of San Pedro, encompassing the Ports of Los Angeles and Long Beach titled *San Pedro Ports Clean Air Action Plan*, released in July 2022 (Ports of San Pedro, encompassing the Ports of Los Angeles and Long Beach 2022). This study encompassed the Ports of Los Angeles and Long Beach. According to the report, "OEMs are also advancing the technology of fuel-cell architectures for top handlers and large-capacity forklifts, although they lag behind battery electric versions for technical viability." Additionally, the report notes that the improvement made to battery electric cargo-handling equipment between 2018 and 2021 was a result of OEMs being able to successfully transfer "enabling technology" (for example, battery packs, electric drive systems, invertors) over from heavy duty electric on-road vehicles. That insight is valuable as it shows that maturity of technology in high-volume production vehicles directly benefits more niche vehicle types. Given the majority of commercial zero-emission vehicles are battery electric rather than hydrogen fuel cell, it is expected battery electric cargo-handling equipment will continue to improve at a faster rate than hydrogen fuel cell variants.

D.1.1. Recommended EV Equivalents

As detailed in Appendix C for the Port of Cleveland (Port), battery electric cargo-handling equipment is the recommended zero-emission technology. The methodology detailed in Appendix C was used to analyze the energy demand for each forklift and reach stacker in Port's fleet to determine the necessary battery capacity for each piece of cargo-handling equipment. Of the 23 pieces of equipment, 11 had empirical fuel consumption data: both reach stackers and 9 forklifts. Empirical fueling records were used to determine the load factor used in the analysis with a 10% error margin being applied. This resulted in a capacity factor of.16 for the forklifts and.28 for the reach stackers. As detailed in Appendix C, equipment of the same type used in the same application can share a load factor even if the engine and vehicle size are different. As such, the forklift load factor of.16 was applied to all the forklifts regardless of the size and lifting capacity. As described in the assumptions in the previous section, a maximum daily operating duration of 8 hours was used to determine the maximum daily energy demand. This maximum daily energy demand was then used to determine what capacity battery was needed for a comparable zero-emission equivalent to ensure 100% daily operational availability for the Port during peak season with no requirement for mid-day charging. Table D-1 lists analysis results and the recommended EV equivalent available today.

Table D-1. Cargo Handling Equipment Energy and EV Equivalent Analysis

Existing Fleet			Energy and Usage Data		Recommended EV Equivalent		
Type	Rated Lifting Capacity (pounds)	Manufacturer, Model	2022 Usage (hours)	Maximum Daily Energy Demand (kWh)	Manufacturer, Model	EV Rated Lifting Capacity (pounds)	Usable Battery Capacity (kWh)
Forklift	5,500	Hyster, H120FT	109	78	BYD, ECB 40	8,800	58
Forklift	15,500	Yale, GDP155	650	111	Kalmar, ECG90-6	19,000	156
Forklift	15,500	Yale, GDP155	733	111	Kalmar, ECG90-6	19,000	156
Forklift	28,000	Hyster, H280X	590	177	Hyster, J300XD	30,000	185
Forklift	28,000	Hyster, H280X	137	177	Hyster, J300XD	30,000	185
Forklift	35,000	Taylor, TH-350L	1019	227	Hyster, J360XD48	36,000	248
Forklift	36,000	Yale, GDP360	695	164	Taylor, ZH-360L	36,000	221
Forklift	36,000	Hyster, H360HD	1288	177	Taylor, ZH-360L	36,000	221
Forklift	36,000	Hyster, H360HD	1108	177	Taylor, ZH-360L	36,000	221
Forklift	36,000	Hyster, H360HD	981	177	Taylor, ZH-360L	36,000	221
Forklift	36,000	Taylor, X360M	141	183	Taylor, ZH-360L	36,000	221
Forklift	52,000	Taylor, TE-520M	263	264	Kalmar, ECG250-12	55,000	353
Forklift	55,000	Kalmar, DCF250-12LB	57	266	Kalmar, ECG250-12	55,000	353
Forklift	55,000	Kalmar, DCG250-12LB	883	266	Kalmar, ECG250-12	55,000	353
Forklift	55,000	Hyster, H550HD	997	285	Kalmar, ECG250-12	55,000	353
Forklift	55,000	Hyster, H550HD	30	285	Kalmar, ECG250-12	55,000	353
Forklift	55,000	Hyster, H550HD	302	285	Kalmar, ECG250-12	55,000	353
Forklift	55,000	Taylor, TX550M	705	253	Kalmar, ECG250-12	55,000	353
Forklift	55,000	Taylor, TX550M	565	253	Kalmar, ECG250-12	55,000	353
Forklift	62,000	Hyster, H620HD	567	285	Kalmar, ECG280-12	62,000	353
Forklift	70,000	Hyster, H700HD	411	285	Kalmar, ECG330-12	72,500	353
Reach Stacker	99,200	Hyster, 45-31 CH Series C222	893	794	Taylor, ZLC-996	90,000	887
Reach Stacker	99,200	Hyster, 45-31 CH Series D222	1033	794	Taylor, ZLC-996	90,000	887

Per Table D-1, for all but one piece of equipment, an EV equivalent is currently available that has a usable battery capacity to ensure uninterrupted operation for a full 8-hour shift. The exception is the Hyster H120FT forklift; the analysis shows it has a maximum daily energy consumption of 78 kWh. While the Port could wait for a forklift of similar capabilities to become available with additional battery capacity or plan to use a hydrogen fuel-cell powered forklift, Jacobs recommends the BYD ECB 40 with only a 58 kWh usable capacity. This is because the forklift is not used often; 109 usage hours were recorded in 2022, which is the equivalent of about 30 minutes per working day on average. In the rare instance the forklift is needed for a full 8-hour day, and 58 kWh of usable energy proves insufficient, a 30-minute mid-day charge session could be used to extend the range. Given the use case of this forklift as detailed by the Port, and supported by the limited hours accrued in 2022, Jacobs does not believe recharge would be needed.

D.2 Yard Tractors

Across North America, yard tractors represent the first equipment to be electrified in port handling equipment at terminals on both the west and east coasts. The system architecture, battery sizing, and powertrain components are direct carryovers from the on-road heavy duty truck industry, which has made significant strides in electrification technologies in recent years. Additionally, yard tractors typically operate within a defined boundary and have predictable operations, making them easier to electrify compared to on-road trucks. While a small percentage of the over 26,000 yard tractors in North America today are electric, deployments have increased exponentially in recent years.

Recent developments in battery technology, charging infrastructure, and government regulations and funding have been the driving force behind the increased availability and capabilities of battery electric yard tractors. As a result, eight manufacturers now offer battery electric variants of their yard tractors. These manufacturers are Kalmar Ottawa, Orange EV, Autocar Trucks, Gaussin, Lonestar, Tico, MAFI, and BYD. While most manufacturers have been focused on developing battery electric yard tractors, their capabilities are still limited and do not work for every use case. As detailed in *2021 Update: Feasibility Assessment for Cargo-Handling Equipment* (Port of Los Angeles and Port of Long Beach Year), battery electric yard tractors could marginally meet the requirements of a single shift. However, two back-to-back shifts totaling 16 hours of operation have not been demonstrated without a charge session between shifts. As such, work is still being done to develop hydrogen fuel-cell yard tractors that have a longer run time between fueling and that can refuel in minutes rather than the hours needed to fully recharge battery electric variants. Specifically, Hyster, Nuvera, and Toyota are working to develop a fuel-cell yard tractor, but so far only prototypes have been built, and these prototypes have faced challenges with onboard storage of compressed hydrogen resulting in limited run times. As noted in the report, while hydrogen fuel-cell yard tractors offer the promise of extended run times and quicker refueling compared to battery electric variants, battery electric yard tractors are at a later stage of technology maturity and are expected to continue to improve in capabilities as battery and charging technology advances.

D.2.1. Recommended EV Equivalents

The methodology detailed in Appendix C was used to analyze the energy demand for each yard tractor in the Port's fleet. Of the three pieces of equipment, none had empirical fuel consumption data. As such, a load factor of.51, sourced from CARB, was used to estimate the average the hourly fuel consumption in gallons per hour. As detailed in the methodology section, equipment of the same type used in the same application can share a load factor even if the engine, vehicle size and GVWR are different. This average hourly fuel usage was used in Equation C-3 to estimate maximum daily energy demand based on an assumed 8-hour shift for a battery electric yard tractor. Table D-2 lists analysis results.

Table D-2. Yard Tractor Energy and EV Equivalent Analysis

Existing Fleet				Energy and Usage Data		Recommended EV Equivalent		
Type	Model Year	Manufacturer, Model	Weight Class	2022 Usage (hrs)	Maximum Daily Energy Demand (kWh)	Manufacturer, Model	Weight Class	Usable Battery Capacity (kWh
Yard Tractor	2001	Ottawa, YT50	Class 8	100	673	BYD, 8Y	Class 8	195
Yard Tractor	1995	Capacity, TJ3000	Class 8	12	757	BYD, 8Y	Class 8	195
Yard Tractor	1995	Capacity, TJ500	Class 8	33	757	BYD, 8Y	Class 8	195

As shown in Table D-2, 8 hours of operation during a single shift at the Port resulted in a maximum daily energy demand of 757 kWh given the methodology used for analysis. In Section 2.1.1 it was assumed that yard tractors would operate 250 working days per year. In 2022, the Port's yard tractors collectively averaged a total of 49 per truck hours annually, equating to an average daily hours of 0.19 hours per day, or less than 1 hour per week. Given the low usage factor it was determined that a 217-kWh battery capable of 2 hours of continuous operation before needing to be recharged would suffice for current yard tractor operation at the Port. It can be assumed that the load factor from CARB does not fully represent actual yard tractor operations, and battery electric yard tractors are more efficient than their diesel counter parts.

D.3 Mobile Harbor Cranes

The port industry is leaning toward electrification for cargo-handling cranes due to their unique position for electrification, given their fixed operating locations with movements confined in a specific area. Additionally, the emission impact is significant, as cargo-handling cranes are the backbone of port operations, resulting in high use and fuel consumption. To this point in master planning study, all equipment reviewed has been mobile while in operation, necessitating the use of batteries and/or hydrogen fuel cells for electrification. Because the mobile harbor cranes are stationary during their primary operational mode loading and unloading cargo, electrification can be achieved by tethering the crane to an medium- or high-voltage grid connection.

Cranes typically have a useful life of approximately 20 years, which means the Port's cranes will not reach their useful end of life until 2035. Due to the modular design of harbor cranes, retrofitting mobile harbor cranes to run off electricity in their primary operational mode is a straightforward and cost-effective way to reduce emissions and fuel use. In most conversions, a crane's diesel engine is retained for use when moving the crane around the Port, but this secondary operational mode typically constitutes a fraction of a mobile harbor crane's annual operational hours.

For new mobile harbor cranes, batteries can be installed for moving the crane or temporarily powering cargo movements while disconnected from the grid. According to discussions with manufacturer Liebherr, many clients in both Europe and North America are choosing to retrofit existing diesel-powered cranes to operate on a grid connection. This approach would allow the Port to use their equipment until its rated end of life, thus saving money while achieving significant emission reductions.

As for new mobile harbor cranes, currently both Kone and Liebherr have fully electric offerings that use batteries to supplement the tethered operational mode. The Port of San Diego is scheduled to receive two 100-ton fully electric mobile harbor cranes from Kone in the fall of 2023. Liebherr is still working to certify their electric mobile harbor crane for the North American market but they expect it to be ready for sale in North America in 2023r. As for hydrogen fuel-cell mobile harbor cranes, ZPMC has been trialing one in Shanghai since 2021. Limited information is available for this deployment. No other announcements could be found regarding the development or deployments of hydrogen fuel-cell powered mobile harbor cranes.

The methodology detailed in Appendix C was used to analyze the energy demand for each of the mobile harbor cranes in the Port's fleet. Both mobile harbor cranes had empirical fueling records which were used to determine the load factor for analysis with a 10% error margin applied, resulting in a load factor of.25. The load factor times each cranes' peak fuel consumption resulted on an estimated average hourly fuel consumption in gallons per hour (g/hr). Assuming a maximum daily operating hours of 8, Equation C-3 from Appendix C was used to determine each crane's maximum daily electrical demands in kWh.
Table D-3 lists analysis results.

Table D-3. Mobile Harbor Crane Energy and Equivalent Analysis

Existing Fleet			Energy and Usage Data		Recommended EV Equivalent		
Model Year	Manufacturer, Model	Rated Lifting Capacity (pounds)	2022 Usage (hours)	Maximum Daily Energy Demand (kWh)	Manufacturer, Model	EV Rated Lifting Capacity (pounds)	Usable Battery Capacity (kWh)
2015	Liebherr, LHM280	185,000	1314	884	Liebherr, LHM280 retrofit	185,000	NA
2015	Liebherr, LHM280	185,000	1052	884	Liebherr, LHM280 retrofit	185,000	NA

As detailed in Table D-2, energy analysis resulted in a peak daily electrical demand of 884 kWh for both cranes. This analysis is not needed to determine a proper EV equivalent; Jacobs recommends running mobile harbor cranes tethered to a medium- or high-voltage grid connection when in primary operational mode. Because the Port's cranes still have approximately 12 useful years left, Jacobs recommends retrofitting the existing LHM280 cranes to operate off a grid-connected medium- or high-voltage tether while still maintaining the diesel engine for harbor movements. Retrofit details have been discussed with Liebherr; based on this discussion, conversion would cost approximately $1million per crane and would take approximately 6 weeks, with 4 weeks to install the new hardware and 2 weeks for testing and commissioning. Because the cranes are not used from January through March, the conversion could be done during this period, resulting in no impact to Port operations. Additionally, required construction to bring grid power to the cranes' operating locations could be done at the same time. An additional benefit to operating the cranes off a tethered grid connection would be that the cranes would not need to be moved at the end of each day back to Warehouse 24 to keep the systems online and power Federal Aviation Administration (FAA)-required aircraft lights. This would further reduce each cranes' dependence on its diesel engine resulting in further emission reductions.

When the Port is ready to procure new mobile harbor cranes to either replace the existing units or expand its fleet, Jacobs recommends purchasing models fitted with batteries that can be used to power the cranes when moving around the Port. Both the Liebherr LHM280 and Kone ESP.5 offer this option. The onboard battery is charged while the crane is tethered to a medium- or high-voltage grid connection; no additional charging infrastructure would needed.

D.4 Rail Locomotive

Electric traction for trains is a technology that dates back to the late 1800s, Electric trains draw their power from an overhead catenary, or a third rail, and are familiar in cities. Diesel-electric locomotives were introduced in the 1930s, and gradually replaced steam for longer distance routes. Diesel-electric was also found to be ideal for switching locomotives, as no addition infrastructure was required. Overhead wires or third rails were a hazard in rail yards.

With the need to decarbonize without resorting to overhead wires, the main alternatives proposed for the Port are battery electric and hydrogen fuel cell. Synthetic fuels have also been proposed to replace diesel. Synthetic fuels must be made from biological sources, requiring significant energy input, and it is arguable whether they truly lead to net zero emissions.

Switcher locomotives are a good application for batteries, as movements are generally confined to a small area and the locomotive is never far from the charging station. Average power demand is low, as a significant amount of time is spent waiting, coupling, and uncoupling, and speeds are low. Full power is only required in short bursts, in contrast to a mainline locomotive that may run at full power for hours at a time. Small battery switcher locomotives powered by lead-acid batteries such as the Zephir Lok-e range have been available for many years, and have generally been used for moving passenger rolling stock. These are often road/rail vehicles and can move between tracks. However, these would not be suitable for moving heavy trains.

Battery technology has made progress in the last decade or so, with lithium-ion chemistry becoming dominant. Energy density continues to increase. The nickel-manganese-cobalt type now common in EVs may have 240 watt hours per kilogram (Wh/kg), and energy densities approaching 500 Wh/kg may be expected. However, these energy densities are still low compared to chemical fuels.

Hydrogen has an energy density that is orders of magnitude higher at 33 kWh/kg; however, it must be compressed or liquefied for storage. Hydrogen can be used to fuel an ICE, but more usually is used with fuel cells, which have more than double the efficiency of an ICE, and also avoids problems with nitrous oxide (NOx) emissions.

The world's first hydrogen-powered train in regular service is Germany's Alstom Coradia iLint. Two prototypes have been running in Lower Saxony, Germany since 2018, with the fleet increasing to 12 in 2022. These are two-car trains, replacing diesel multiple units, and store hydrogen in roof-mounted vessels at 350 bar, giving a range of around 500 miles. Siemens, CAF and others are developing similar products.

PESA in Poland has developed a fuel-cell powered switcher locomotive, the SM42-6Dn, which gained approval for operation in June, 2023. This four-axle locomotive has two fuel cells with 170 kW total output, in addition to a battery powering four 180-kW motors. With 175 kilograms (kg) of hydrogen stores, it can operate for up to 24 hours. There do not appear to be any high-powered hydrogen fuel-cell locomotives under development , based on Jacobs' knowledge of the global industry.

For the purposes of this master plan, Jacobs experts have researched unique industry knowledge perspectives on the topics of rail locomotive electrification. In the United States, Progress Rail and Wabtec have both been developing battery powered locomotives with the same capabilities as their 4,500-hp mainline locomotives, except for operating range. Wabtec tested an FLXdrive locomotive with BNSF in 2021 and has orders from several iron ore railroads in Western Australia. The first locomotive will be delivered to Roy Hill in Australia at the end of 2023, with 7-megawatt hour (MWh) capacity; this will operate hauling 40,000-tonne trains in combination with three diesel-electric locomotives, with charging mainly by regenerative braking. Additionally, Progress Rail has already supplied a 1.9 MWh battery switcher locomotive to Vale in Brazil and has an order for four SD70J locomotives for BNSF to be delivered in 2024.

Switcher locomotives are also a good application for batteries, as movements are generally confined to a small area and the locomotive is never far from the charging station. Average power demand is low, as a significant amount of time is spent waiting, coupling and uncoupling, and speeds are low. Full power is only required in short bursts, in contrast to a mainline locomotive that may run at full power for hours at a time. Small battery shunter/switcher locomotives powered by lead-acid batteries such as the Zephir Lok-e range have been available for many years, and have generally been used for moving passenger rolling stock. These shunter/switcher locomotives are often road/rail vehicles and can move between tracks. However, these would not be suitable for moving heavy trains.

Hydrogen fuel cells may also be used for switcher locomotives, with the advantage that more energy can be stored, filling at a faster rate than charging with the equivalent electrical energy. However, because of inefficiencies in electrolyzers and fuel cells, approximately three times more energy is required. The cost of delivering hydrogen and storing it onsite is also significant. A fuel-cell locomotive also has more components requiring maintenance. In general, hydrogen will have higher operating costs than batteries.

There are also no commercially available fuel-cell-powered switching locomotives on today's market. However, in 2025, there will be a demonstration of a pilot locomotive in West Sacramento, California led by Valley Vision, funded primarily through the California Energy Commission. As such, the recommended zero emission technology for the Port switcher is battery electric.

The methodology detailed in Section 4.1.2 was used to analyze the energy demand for the switching locomotive in Port's fleet. The locomotive did not have empirical fuel consumption data. As such, a load factor from CARB of.51 was used to assume the average fuel consumption in gallons per hour. The estimated hourly fuel consumption as well as an assumed maximum 8 hour daily shift, the maximum daily energy demand was determined as detailed in Table D-4.

D.5 Light-Duty Car and Truck

Globally, the fast growing zero-emission technology for light-duty passenger vehicles is battery electric. Given their use case, current lithium-ion battery technology can provide sufficient energy for majority of applications, and rapidly evolving quick charging technology is enabling battery electric light-duty vehicles to be increasing useful in more intensive duty cycles. To date, every major OEM in the US have BEVs available for purchase, with Ford, Rivian, and Chevy having battery electric pickups for sale. Ram and Tesla have announced a battery electric pickup, but they are not available for sale yet. Still, most options are confined to smaller sedans and SUVs, but more battery EVs types are becoming available each year. As for medium duty pickups, there are currently no available models directly available from OEMs. However, retrofit companies like Lightning E Motors and Phoenix Motorcars, can provide class 3 battery electric pickups and work trucks based on Ford and Chevy chassis.

Currently, battery electric light-duty vehicles sales are 100 times that of hydrogen fuel-cell vehicles with majority of hydrogen fuel cell deployments being in California due to their available fueling infrastructure that is not available in other states. Only two OEMs, Hyundai and Toyota, currently offer hydrogen fuel cell models and no models from other OEMs have been announced. Many OEMs have abandoned their light-duty vehicle hydrogen fuel cell programs to focus on battery electric. Given the increasing investment by OEMs and the federal government to expand charging infrastructure and develop US based battery manufacturing, this is no expectations OEMs will change focus to hydrogen fuel cell. Additionally, the pace of improvement of battery technology, increasing energy density and shorter charge times, will continue to make BEVs more compelling while dissolving the current advantages of hydrogen fuel cells vehicles.

As detailed in the above Section, light-duty vehicle manufacturers have mostly abandoned their hydrogen fuel cell programs in favor of battery electric. While hydrogen fuel vehicles offer quicker refueling times and extended ranges, those advantages are quickly being dissolved as battery technology rapidly improves. The fact that every home and business in America has the fueling infrastructure needed for battery EVs is a large driving for OEMs selection of battery electric. Currently, hydrogen is expensive and there is a limited supply with many states having zero hydrogen fueling infrastructure. With the need to rapidly deploy zero-emission vehicles, this limitation significantly undermines hydrogen fuel-cell vehicles case. Additionally, given the availability of various battery electric models, the preferred technology for the Port is battery electric

The methodology detailed in Section 4.1.3 was used to analyze the energy demand for each light-duty vehicle in Port's fleet. Of the five pieces of equipment, all had either empirical annual fuel consumption and mileage data or well informed assumptions. Additionally, the Port provided peak daily mileage which was used to inform the maximum daily energy demands for each recommended EV equivalent. Results are detailed in Table D-4.

Table D-4. Light Duty Truck and SUV Energy and EV Equivalent Analysis

Existing Fleet		Energy and Usage Data			Recommended EV Equivalent		
Model Year	Manufacturer, Model	2022 Usage (miles)	Peak Daily Mileage (miles)	Maximum Daily Energy Demand (kWh)	Manufacturer, Model	Combined MPGe	Usable Battery Capacity (kWh)
2018	Chevy, Colorado	3800	250	120	Ford, F150 Lightning 4WD Extended	70	131
2016	Ford, F250	5114	50	25	Ford, F150 Lightning 4WD Standard	68	98
2013	Ford, F350	3947	50	41	Lightning E Motors, ZEV4	41	108
2022	Ford, Explorer	5115	50	17	Ford, Mach-E RWD	101	72
2014	Ford, Explorer	5000	50	17	Ford, Mach-E RWD	101	72

D.6 Other Support Equipment

D.6.1. UTVs

For light-duty UTVs, the industry is beginning to offer high-capacity lithium-ion batteries in lieu of lead-acid batteries, which were used in older-generation golf cart-style platforms. The introduction of high-capacity and high-power lithium-ion batteries enables new electric UTVs to have performance that rivals and sometimes exceeds that of their ICE equivalents. However, available electric UTVs are primarily aimed at the consumer market and lack many of the features and functionality needed by commercial clients, such as a hydraulic power take-off (PTO) needed to operate plows and other attachments, and cabin heating and cooling packages. It is expected that as this space matures, manufacturers such as Bobcat, Polaris and John Deere will begin offering full battery electric versions of their commercial UTVs. Hydrogen versions are not projected to be produced in the short- to mid-term and no announcements have been made from any major OEM regarding development of hydrogen fuel-cell UTVs.

The Port did not have empirical data about UTV fuel consumption. The CARB load factor of.42 was used to assume average fuel consumption in g/hr. Table D-5 lists estimated hourly fuel consumption, an assumed maximum 8-hour daily shift, and the maximum daily energy demand.

Table D-5. UTV Energy and EV Equivalent Analysis

Existing Fleet		Energy and Usage Data		Recommended EV Equivalent	
Model Year	Manufacturer, Model	2022 Usage (hours)	Maximum Daily Energy Demand (kWh)	Manufacturer, Model	Usable Battery Capacity (kWh)
2022	Bobcat, UW56	185	161	Bobcat, T7X (Skidsteer)	54
2013	Polaris, Brutus HD	300	66	Polaris, Ranger XP Kinetic	27

One example of a commercially available commercial battery electric UTV is the Polaris Ranger Xp Kinetic manufactured by Polaris utilizes a 29.8-kWh lithium battery pack capable of approximately 80 miles of driving range on one charge. Given the low usage hours of the current Port UTVs, it is anticipated that this battery capacity of range could still meet the Port's operational needs.

An important consideration is that the current electric Ranger UTV product does not provide the same capabilities as the current diesel UTV vehicles with PTO auxiliary power connections, which are required for the various front attachments, such as the bucket attachment currently used on the Bobcat UW56. A possible alternative EV replacement strategy for the Bobcat UW56 could be to procure both a Ranger Kinetic Xp UTV along with an all-electric skid steer, such as the Bobcat T7X. The all-electric T7X has a 60-

kWh battery and can use multiple attachments, including a bucket attachment capable of soil and snow clearing.

D.7 Generators

Zero-emission generators are a rapidly developing market with available options increasing from both established manufacturers and startups. Currently, diesel generators are the primary method for supplying power at temporary construction sites, remote or off grid locations, festivals and more. But due to the recent advancements in lithium battery technology and an associated drop in costs, mobile battery electric generators are providing an alternative to existing diesel generators. Battery electric models are available from Atlas Copco, Portable Electric Ltd., Moxion Power Co., RIC Power Corporation, Caterpillar, Inc., and more. These units are designed to operate on their own or paired with an external power generation source that can trickle charge the batteries while they provide the demand response needed to run external loads. The external power generations can consist of solar panels, low-power grid connection (120 volts [v]/240v), a diesel generator, and more. Additionally, most of the available battery electric models are designed to be charged by existing CCS1 or J1772 EV chargers. Manufacturers are also working on hydrogen fuel-cell mobile generators, but fewer options currently exist. Generac offers an 80-kW hydrogen fuel-cell powered generator that pairs 44-kWh of batteries with a hydrogen fuel cell and high-pressure hydrogen storage tanks to provide extended zero-emission runtime. Limited availability of hydrogen fuel and the cost of fuel cells has pushed manufacturers to focus on developing battery electric generators.

The methodology detailed in Appendix C was used to analyze the energy demand the Port's mobile generator. The Port did not have empirical fuel consumption data for the generator, and no load factor was available from CARB. The EPA load factor of.43 was used to assume average fuel consumption in g/hr. Table D-6 lists estimated hourly fuel consumption, an assumed maximum 8 hour daily shift, and the maximum daily energy demand.

Table D-6. Generator Energy and Battery Electric Equivalent Analysis

Existing Fleet			Usage and Energy Data		Recommended EV Equivalent		
Model Year	Manufacturer, Model	Rated Output (kW)	2022 Usage (hours)	Maximum Daily Energy Demand (kWh)	Manufacturer, Model	Rated Output (kW)	Usable Battery Capacity (kWh
2022	Kubota, GL14000	12	46	57	Portable Electric, Voltstack 30k	27	72

*Table note goes here.

Continuous 8 hours operation of the generator, given the assumed average hourly fuel consumption, resulted in a maximum daily energy demand if 57 kWh. The recommended electric equivalent has more than enough energy storage to replace the Kubota GL14000 without any impact to Port operations. The Voltstack 30k., for example, has additional capabilities compared to the existing diesel generator as it can supply both single phase 120V/240V power and 3-phase 240V power. Additionally, the unit could be used to supply zero-emission mobile charging to other battery electric equipment in the Port's fleet if paired with a portable J1772/CCS1 EV charger.

D.8 Work Barges

Due to the energy intense duty cycle of boats, the zero-emission boat industry is in its infancy, with much of the initial focus being on electrifying large passenger/car ferries and consumer boats. These boat types have shorter and less intensive duty cycles with plenty of dwell time to recharge. A popular trend in the zero-emission boat industry is converting ICE-powered boats to battery electric. Boats are well-positioned for retrofits due to the modularity of their construction. Additionally, boat hauls typically have a long life, so being able to convert from ICE to battery electric enables operators to meet their emission targets while still using a vessel for its full useful life. Two major companies offer retrofit kits, including Torqeedo and Green Yacht. Additionally, these companies can provide battery electric propulsion kits that can be installed in new boats. In the United States, electric boat deployments are ramping up, with smaller electric vessels being deployed in increasing volume. For example, the Port of San Antonio has deployed 48 27-foot passenger boats built by Lake Assault and powered by Torqeedo (Lake Assault Boats 2023) Hydrogen and ammonia are being studied for use in large ocean-going vessels to cut emissions, as batteries are unable to serve theses vessels' intensive energy demands and long travel times, but for smaller vessels like the ones operated by the Port, the industry's focus has primarily been on using battery electric technology with research continuing on hydrogen fuel cells for use as range extenders.

The methodology detailed in Appendix C was used to analyze energy demand for the Port's work barges. The Port did not have empirical fuel consumption data for the barges, and no load factor was available from CARB. The EPA load factor of.35 was used to assume average fuel consumption in gallons per hour. Table D-7 lists estimated hourly fuel consumption, assumed maximum 8-hour daily shift, and maximum daily energy demand.

Table D-7. Work Barge Energy and EV Equivalent Analysis

Existing Fleet			Usage and Energy Data		Recommended EV Equivalent		
Model Year	Manufacturer, Model	Maximum Shaft Power (kW)	2022 Usage (hours)	Maximum Daily Energy Demand (kWh)	Manufacturer, Model	Maximum Shaft Power (kW)	Usable Battery Capacity (kWh)
2012	Lake Assault, 25' Barge	165	920	519	Torqeedo, Deep Blue 100i	100	77.6
2012	Lake Assault, 25' Barge	165	920	519	Torqeedo, Deep Blue 100i	100	77.6

D.9 References

City of Los Angeles Harbor Department. *Port of Los Angeles Everport Advanced Cargo Handling Demonstration Project, Task 2 Equipment Summary Report for Taylor Machine Works, Inc.* , 2021

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Ports of Los Angeles and Long Beach. 2021. *2021 Update: Feasibility Assessment for Cargo-Handling Equipment. https://polb.com/port-info/news-and-press/san-pedro-bay-ports-release-final-2021-cargo-handling-equipment-assessment-08-25-2022/*

Appendix E
Hydrogen Fueling and Industry Infrastructure

E. Hydrogen Fueling and Industry Infrastructure

As the demand for sustainable and zero-emission transportation solutions grows, the use of hydrogen fuel cell technology in the cargo handling sector has emerged as a promising alternative to traditional diesel-powered equipment. Fleet operators seeking to convert their fleets to zero emission equipment should thoroughly evaluate the benefits of battery electric and hydrogen fuel cell technologies and their required infrastructure in terms of total cost of ownership (TCO) (including upfront capital, fuel, and maintenance costs) and operational feasibility (including range, payload, and refueling times) to inform planning efforts.

E.1 Hydrogen Production and Delivery

Fleet operators have two methods available for sourcing hydrogen: onsite generation and hydrogen delivery from centralized production facilities.

E.1.1. Onsite Generation

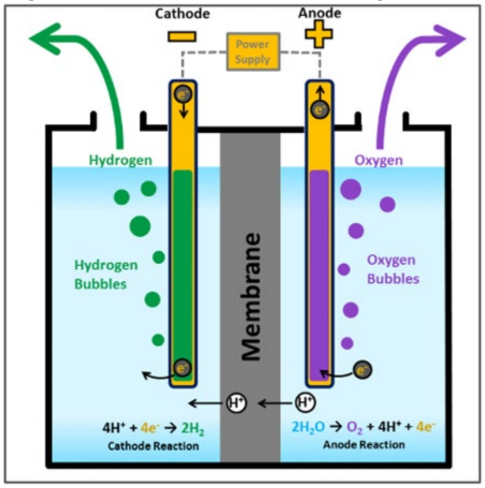
The options for onsite generation methods are steam methane reformation (SMR) and electrolysis. SMR is a process that involves combining methane and steam to produce hydrogen and carbon dioxide. If the methane is sourced from biowaste, the hydrogen produced is sometimes considered renewable, because the SMR process offsets methane emissions in exchange for carbon dioxide emissions, a less potent greenhouse gas. (U.S. Environmental Protection Agency https://www.epa.gov/gmi/importance-methane#:~:text=Methane%20is%20the%20second%20most,trapping%20heat%20in%20the%20atmosphere)

Electrolysis uses electricity to split water molecules, producing only hydrogen and oxygen. Figure E-1 is a schematic of the electrolysis process. Electrolyzers are energy intensive and difficult to justify economically on a smaller scale of use, such as 500 kilograms per day. Electricity prices must be low for this option to be cost competitive. Additionally, the equipment required for electrolysis has a large footprint, which ports may not be able to accommodate if space is limited.

Based on knowledge gathered through various hydrogen infrastructure projects, it was observed by CTE that both SMR and electrolysis require at least $5 million in capital expenditure in addition to the cost of the compression, storage and dispensing equipment to produce approximately 400 to 500 kilograms of hydrogen per day, which would be enough to support about 15 fuel-cell electric top loaders at 30 kilograms (kg) each.

In general, Jacobs and CTE recommends using of centralized production facilities with delivered supply for fleets, as the additional capital costs and managing unreliable fuel production units significantly increase complexity. However, as SMR and electrolysis technologies evolve and become more reliable, this onsite generation may become a more viable option to improve resilience.

Figure E-1. Overview of Electrolysis Process

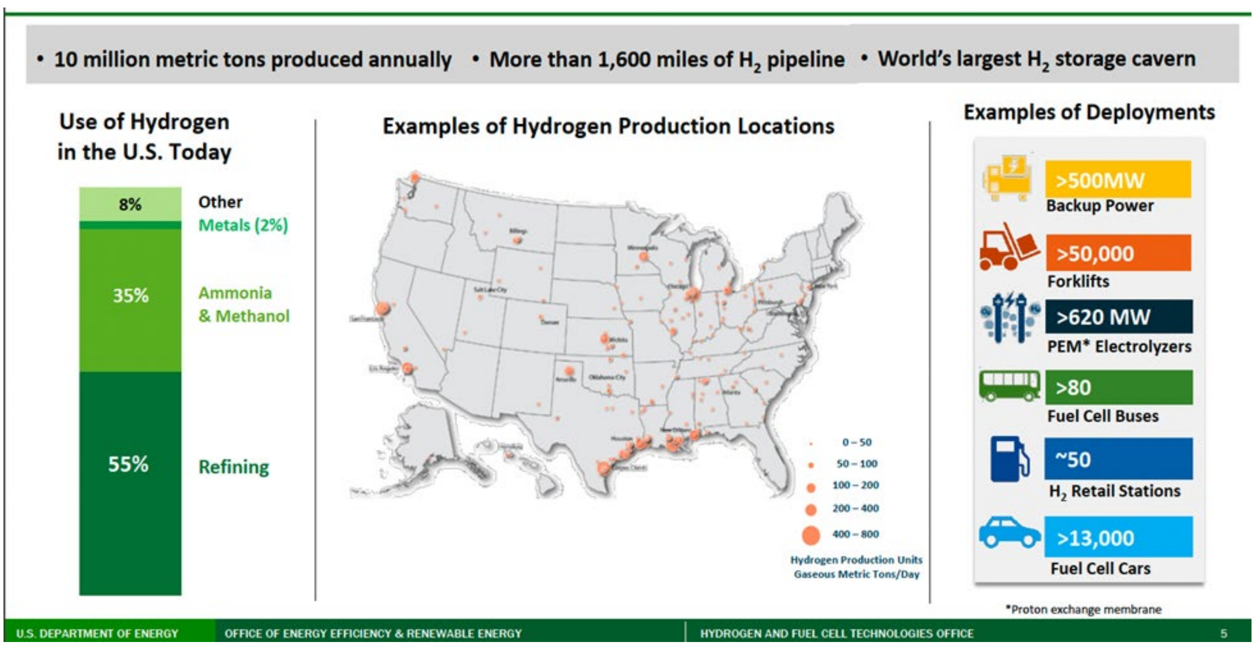


Source: U.S. Department of Energy

E.1.2. Existing Centralized Production Centers

Figure E-2 is a snapshot of the overall hydrogen industry, which has primarily focused on refining and ammonia and methanol production, rather than transportation applications.

Figure E-2. U.S. Hydrogen Production



Source: Source

The key difference is that fuel cells, as opposed to refineries/industrial applications, require 99.97% pure hydrogen to avoid contamination of the membrane, as is specified in SAE J2179. Therefore, the hydrogen from a majority of production facilities is not suitable for use in fuel cell applications today.

A majority of the hydrogen production facilities suitable for the transportation industry serve the California market. Developments in the Midwest region have been slower; however, Stark Area Regional Transit Authority in Canton, Ohio, started a fuel-cell bus program in 2016, initially supplying hydrogen from an

Air Products facility in Ontario, Canada. Another Midwest transit agency, Champaign-Urbana Mass Transit District, is operating two 60-foot fuel-cell electric buses, powered by fuel produced by an onsite electrolyzer as the regional supply options are currently limited.

Based on CTE and Jacobs' combined knowledge in the industry, this section summarizes the various companies and projects are in progress or planned. Plug Power, Air Products, and other producers have plans to develop hydrogen supply nodes across the United States to meet the growing demand for hydrogen in transportation applications. One potential opportunity for expansion of hydrogen production is the US Department of Energy's (DOE's) Regional Clean Hydrogen Hubs Program, aimed at commercializing various end use applications of hydrogen around the United States in 6 to 10 regions over the next 10 years. Based on publicly available information, the Great Lakes region is involved in two hydrogen hub proposals, referred to as the Great Lakes Clean Hydrogen Hub coalition (GLCH) and the Midwest Alliance for Clean Hydrogen. Several other proposals were also submitted from neighboring regions in the upper Midwest and Appalachia, which could also have positive impacts on hydrogen supply to the Great Lakes region. While the details of the proposals have not been released, it can be stated with reasonable confidence that should a Midwest Hub be awarded funding, the hydrogen production in the region would dramatically accelerate in the next 5–10 years. DOE is expected to release awards before the end of 2023.

E.1.3. Hydrogen Delivery

Despite a push in recent years toward electrolytic, renewable hydrogen supply, the majority of all hydrogen produced in the United States is reformed at large, centralized natural gas SMR facilities and is then transported to application sites. Hydrogen can be delivered in either liquid or gaseous form. Currently gaseous and liquid hydrogen are delivered to fueling stations via tube trailer. As a gas, hydrogen may be delivered via pipeline or tube trailer; however, with current technologies, liquid hydrogen requires trailer deliveries.

Tube trailer delivery is a common method of delivering gaseous hydrogen. Trailers can transport up to 1,200 kg of hydrogen at 500 bar. Gaseous hydrogen delivery costs are as low as $12 per kg, but can be as high as $20 or more per kg.

Liquid hydrogen is considerably more energy dense than the gaseous form, allowing a greater amount of energy per delivery; trailers can deliver up to about 4,000 kg of liquid hydrogen. However, liquifying the hydrogen, or liquefaction, is an energy intensive process. The energy required to liquify hydrogen is roughly equal to 15–30% of the total energy contained within the fuel itself. Costs for delivered liquid hydrogen vary significantly by region, depending on regional energy markets and the transportation costs based on proximity to the production facility. In California, transit agencies typically pay about $10 to $13 per kg for delivered liquid hydrogen. However, the California market is considered to be the most advanced with three major liquefaction facilities, seven transit agency stations, and over 50 light-duty hydrogen stations in operation.

E.1.4. Refueling

In the early stages of market development, a key challenge for projects is matching vehicle deployments to their accompanying infrastructure and identifying a fuel supply option and/or constructing the fueling facilities in time to match vehicle deployments. Temporary refuelers can offer a solution, but infrastructure continues to be a primary bottleneck in slowing the advancement of Fuel Cell Electric Cargo Handling Equipment (FCECHE). While EVs chargers are often simpler/easier to install, they are limited in the number of vehicles they can support. In contrast, hydrogen fueling facilities are more complex and costly, but can support many more vehicles, enabling additional vehicle demonstrations and technological advancements.

E.1.4.1. Infrastructure Overview

There are currently two available options for hydrogen refueling infrastructure, liquid and gaseous. A fleet operator's decision to construct a liquid or gaseous station depends largely on cost, which is driven by the quantity of hydrogen required at the given facility. Both options can be configured to support H35 or H70 refueling. The following section provides a brief overview of each option and considerations for fleets.

E.1.4.1.1 Liquid Hydrogen Refueling Station

The key components of a liquid hydrogen refueling station are:

- A liquid hydrogen storage tank that typically holds between 15,000 and 25,000 gallons of liquid hydrogen
- Cryogenic liquid hydrogen pumps
- High-pressure vaporizers
- High-pressure cascade or buffer storage tubes
- Pre-cooling unit (optional)

Liquid hydrogen refueling stations receive deliveries of liquid hydrogen from centralized production/liquefaction plants via tankers. The liquid hydrogen is pumped from the storage tank to the vaporizers, which elevate the pressure and feed the hydrogen, now a gas, to the high-pressure cascade storage, or directly to the vehicle. Operators can further pre-cool the hydrogen using additional chiller units to mitigate expansion and increase the fill rate. An example of a liquid hydrogen storage tank refueling station is shown in Figure E-3.

Figure E-3. Example of a liquid hydrogen refueling station

Source: Orange County Transportation Authority

E.1.4.2. Gaseous Hydrogen Refueling Station

The key components of a gaseous hydrogen refueling station include:

- Gaseous hydrogen supply source
- Tube trailer deliveries
- Gas compressors
- High-pressure gaseous storage tanks
- Refrigeration system for cooling of gas prior to dispensing

- Onsite generation such as SMR or electrolysis (optional)

Gaseous stations require either deliveries of hydrogen in tube trailers, or onsite generation assets such as SMR or electrolyzer units. Since the gaseous supply is at a low pressure, it requires compression to reach the high pressure required for fueling. Once the gas is compressed, it flows to the buffer storage. A low volume of gas is stored at high-pressure and is fueled from that location into the bus. Prior to fueling, a heat exchanger cools the gas.

Typically, fleets with expected demand over 300 kilograms will find it more affordable to install a liquid hydrogen refueling station due to the costs associated with taking multiple deliveries of gaseous hydrogen per day to fulfill demand. CTE and Jacobs currently estimates one delivery tube trailer of gaseous hydrogen has a storage capacity of 400 kilograms and the usable quantity is less. The cumulative costs of delivery are expensive for operators once a delivery is required almost every day.

Lastly, it is important to design infrastructure according to vehicle refueling requirements. H35 and H70 refueling can be collocated and use common storage equipment, but may require a larger footprint for additional compression. As the market for station developers continuously evolves, CTE recommends fleet operators conduct a request for proposal process to allow design-build contractors to propose a facility design that meets their needs.

E.2 Future of the Industry

E.2.1. Technology

fuel-cell electric vehicles (FCEVs) are expected to play a major role in reducing emissions within the medium- and heavy duty transportation sector. However, increasing the scale of this technology requires significant investment in refueling infrastructure, vehicle and equipment manufacturing, and innovation to reduce capital costs and improve fuel cell durability. Hydrogen has been successfully deployed in off-road applications that require high payloads and high uptime, such as forklifts. Ports with high-traffic container terminals that require cargo and materials handling equipment with high uptime are expected to shift to hydrogen technologies (U.S Department of Energy, 2023). There are a limited number of pilot projects/demonstrations which show promise, but these vehicles are typically not available for purchase. The purpose of demonstration vehicles is to prove out the viability of a technology in real world applications, however, there is considerable development effort required to bridge the valley of death gap to make a vehicle commercially available for other operators.

For any vehicle types which do not yet have a clear commercialization pathway, CTE and Jacobs recommends the Port of Cleveland pursue a demonstration program for a small number of vehicles (2-5) with a vehicle OEM or integrator, such as Hyster-Yale, Capacity, or UES, depending on the particular application, with a temporary refueling solution. This process should involve direct engagement with OEMs and suppliers to determine their product timelines and ability/interest to integrate fuel cells into new vehicle applications. Through this approach, final supplier selection could be made through a request for information (RFI) or RFP process.

E.2.2. Range/Duty Cycle

Early-stage demonstrations, such as the previously mentioned Hyster-Yale ETL at POLA, show a need for additional fuel storage onboard fuel-cell electric to run three consecutive shifts. However, two constraints preventing the addition of fuel tanks at H70 are space onboard the vehicle, and weight. Increased vehicle weight reduces energy efficiency, leads to increased tire wear, and impacts payload capabilities. One potential solution is the integration of either liquid or cryo-compressed hydrogen onboard, which would offer more energy per unit volume over H70, similarly increasing range capabilities. While there are no known deployments of port equipment using liquid or cryo-compression port equipment, Daimler/Freightliner is currently testing a class 8 fuel-cell electric truck with liquid fuel onboard to extend range for long haul applications. Similar technology may be adopted in the Port's cargo-handling equipment sectors to improve range and duty cycle capabilities for FCECHE. Additional range and duty cycle improvements may come from optimized control algorithms for fuel cells and improved end-to-end drivetrain efficiencies.

E.2.3. Fueling Speed

The SAE J2601-5 is a prospective update to the J2601 standard analogous to J2601-1 for heavy duty vehicles. The protocol would enable flow rates for H35 of up to 7.2 kg per minute (or 120 grams per second), and for H70 of up to 18 kg per minute (or 300 grams per second). Once adopted, this standard will significantly improve fueling times for fleet operators of fuel-cell electric vehicles (FCEVs). Assuming a 4-day supply of hydrogen is required for resilience of operations, at scale, a fully hydrogen fleet would require roughly 4,100 kilograms of accessible hydrogen storage. This would likely require at least an 18,000-gallon (or up to 25,000 gallon) liquid hydrogen storage tank. Similar hydrogen fueling stations at transit agencies fueling at 350 bar require a footprint of 90 feet x 33 feet. Similar stations built at transit agencies typically require between 200-500 kW of power and can provide fuel for up to 100 buses. A station of this scale may cost about $7M-$9M depending on the dispenser configuration for H35 vs. H70 and several site-specific factors. Further analysis of the vehicle applications and likely refueling pressures (H35 vs. H70) should also be considered for more accurate estimates of station footprints, electricity demand, and cost.

E.3 Other Market Factors

Despite the impending increase in demand generated by statewide mandates, OEMs today are not yet prepared to manufacture vehicles at scale to meet the growing demand. Continued investments in projects with scaled vehicle deployments tied directly to their respective infrastructure is critical to bridge the commercialization gap of medium and heavy duty zero-emission technology before fleets can meet these strict regulations.

For all of the vehicle types, the capital costs of the vehicle and infrastructure remains a key barrier to adoption. These costs are driven by the high costs associated with research and development and diseconomies of scale at the initial low volumes of production. Limited production volumes result in higher manufacturing costs per unit, which subsequently translates into higher vehicle capital costs. Government subsidies can help offset the capital costs of these projects.

Additionally, the cost of hydrogen fuel is a major barrier for fleets relying on hydrogen to fulfill the requirements of their operations. Hydrogen fueling infrastructure is still in the early stages of development, resulting in limited availability and high fuel costs compared to traditional fuels. Current retail prices in California exceed $26 per kg at times, while the industry requires a target price of between $5 and $6 per kg to be competitive with existing diesel prices. The industry is hopeful that the DOE's Clean Regional Hydrogen Hubs Initiative will reduce the cost of hydrogen and commercialize hydrogen production and offtake technologies. However, it is not yet a commoditized fuel, making costs highly variable and susceptible to market pressures. Addressing this challenge requires concerted efforts in expanding the hydrogen infrastructure network and increasing demand volume to reach economies of scale.

E.4 References

https://www.epa.gov/gmi/importance-methane#:~:text=Methane%20is%20the%20second%20most,trapping%20heat%20in%20the%20atmosphere

https://www.energy.gov/articles/doe-releases-new-reports-pathways-commercial-liftoff-accelerate-clean-energy-technologie

Appendix F
Charging Infrastructure and Industry Overview

F. Charging Infrastructure and Industry Overview

The maturity of both lithium-ion batteries and the charger products to recharge those batteries have significantly innovated over the last 10 years, and continue to be refined and developed. This section overviews current trends and technology adoption forecasts, as well as an overview of standards and typical nomenclature.

F.1 Charging Infrastructure Overview

In addition to the hydrogen infrastructure, this master plan includes electric vehicle supply equipment (EVSE) infrastructure for the Port of Cleveland (Port) cargo-handling equipment. EVSE is a new infrastructure typology describing the equipment or system that supplies electricity to an electric vehicle (EV). EVSE, commonly called EV chargers, have advanced rapidly since its introduction. Within the United States, charging levels are gathered into the following three broad categories:

- **Level 1:** Uses the common 120-volt household outlet, and is typically referred to as "trickle charging." The power output from this type of charging is approximately 3 kilowatts (kW) or less in alternating current (AC), and while this is adequate for a low-use vehicle that can be plugged in overnight, it is not suitable for operational use.
- **Level 2:** Uses 208- to 240-volt with a total power output of 7 kW to 19.2 kW in AC (typically). This is a much higher power output than Level 2 and is normally suitable for any standard light vehicle that will be plugged in for multiple hours.
- **Level 3:** Uses 50-kW+ direct current (DC) connections to provide a much greater level of power to EVs. This is the standard charging in any case where the vehicles will need to be charged and ready to be used in a short period of time.

Prior to 2016, most EVs charged at 3 kW AC, which was adequate to fully recharge most batteries (typically up to 24 kWh) overnight. Rapid charging DC[1] technology has developed much faster than AC technology,[2] giving consumers a faster method to recharge. However, only some plug-in models before 2016 can rapidly charge, while all new recent US plug-in models can be rapidly charged. The roll-out of rapid chargers at 150 kW+ is now beginning across the US. Most are also designed to deliver 50kW DC charges to rapid chargeable vehicles to combat the current lack of high-power charging demand.

F.2 SAE J1772, SAE CCS1, and North American Charging Standard Connectors

Jacobs has advised clients on EV charging infrastructure for years, and have observed the following trends on EVSE connectors and connector types. Over the last 10 years various connector types have been introduced, but only in the last 3 years has there been a coordinated effort to standardize connector types for road-going passenger and truck vehicles, spearheaded by SAE in North America. To date, SAE has introduced the multiple standards, including the SAEJ1772 connector, that are gaining broad adoption by road-going passenger vehicle and truck original equipment manufacturers in North America.

The most common platform is the J1772 connector, also known as CCS1 in the DC charging pin configuration. All available light-duty passenger vehicles in the consumer market use J1772 and CCS1 as the connector type in North America.

[1] DC technology is typically used for fast charging of EVs as it is constant power/ direct current stored in batteries of EVs (and other electronic devices such as mobile phones).

[2] AC technology is alternating current/ power from the power grid and is converted to DC by the car. It is used for charging EVs at various speeds.

Figure F-1. SAE J1772 CCS1 Connector

Source: REMA Group

In June–July 2023, Ford, GM, Rivian, Volvo, Mercedes, and Polestar have announced that in future vehicle offerings they will offer North American Charging Standard connector (NACS) inlets on their vehicles in lieu of CCS1 connectors. This takes advantage of the existing Tesla Supercharger DCFC network, which uses NACS connectors.

Figure F-2. North American Charging Standard Connector

Source: Tesla

The charging needs of battery electric locomotives on the market vary among three methods of connectors/plugs: CCS1, megawatt charging standard (MCS), and inverted pantographs, or the J3105-1 connector.

F.2.1. SAE MCS

In 2022, SAE announced the manual plug-in cable connector standard, the MCS connector. The connector and cable can transfer power at a maximum of 1,250 volts and 3,000 amperes, equating to charge rate of 3.75 megawatts (MW) from a DC charger to a battery EVs, via a handheld charging plug. The MCS was a result of the CHArIN initiatives in 2018 to “define a new commercial vehicle high-power charging standard to maximize customer flexibility.” CHArIN previously developed the CCS specification. Current CCS products on the market from REMA and Phoenix Contact allow for liquid-cooled cable versions up to 1,000 volt and 500 amperes, equating to 500 kW. 500 kW already exceeds many heavy duty vehicles charge port amperes ratings, meaning that little road-going vehicles today can accommodate the maximum CCS1 output, let alone MCS power levels. It is expected that MCS will start to become more commonplace in the marine ferry, mining, and off-road port handling equipment markets. It will not enter the transit bus market for another decade given the already popular use of J3105 charging.

Figure F-4. Cavotec MCS Cable

Source: Cavotec

F.2.2. Future-Looking Trends in EVSE

Based on current industry trends in the heavy duty port equipment handling space, as well as the current connector types being used on the EV equivalent equipment surveyed, Jacobs recommends implementing the connector types listed in Table F-1.

Table F-1. EVSE Connector Recommendations

Vehicle Type	Near Term Deployment (0–3 years)	Long Term Deployment (3–10 years) (Forecasted Trend)
Forklift (<34,000pounds)	80V REMA/Anderson SB Connector	SAE CCS1
Forklift (>60,000pounds)	SAE CCS1	SAE CCS1
Forklift (35,000–54,000pounds)	SAE CCS1	SAE CCS1
Forklift (55,000–60,000pounds)	SAE CCS1	SAE CCS1
Heavy Duty Equipment and Construction Equipment (Payloader)	SAE CCS1	MCS
Heavy Duty Trucks (over 26,000 pounds.) (Yard Tractors)	SAE CCS1	SAE CCS1
Mobile Crane	N/A[a]	N/A[a]
Rail Locomotives	SAE CCS1	MCS
Pickups and Light-Duty Basic	SAE J1772	NACS
Portable Generator	SAE CCS1	NACS
Reach Stacker	SAE CCS1	SAE CCS1
Small Off-Road and Other Equipment (UTVs and manlifts)	SAE J1772	NACS
Boat	SAE CCS1	SAE CCS1

[a] Mobile Harbor Cranes utilize a separate connection standard dictated by shorepower standard IEC/ISO/IEEE 50005-1.

F.2.3. EVSE Codes and Standards

All EVSE in the U.S. must comply with codes and standards set forth for the safety and consistency of installers and owners (NREL 2020):

- National Electrical Code—Specifically, Article 625, *EV Charging System Equipment*, which discusses the connection and installation of EVSEs

- Society of Automotive Engineers—Standard J-1772, *EV Conductive Charge Coupler* ensures operational and functional requirement for plug-in connectors and vehicle inlets
- Underwriters Laboratories (UL)—Standard UL 2251, *Standard for Plugs, Receptacles, and Couplers for Electric Vehicles* covers the design and safety of plugs, cords, receptacles, and connectors
- UL Standards 2594 and 2202, *Standard for Safety Electric Vehicle Supply Equipment* are both safety standards for EVSEs and charging system equipment
- International Organization for Standardization (ISO)—ISO Standard 15118, *Road Vehicles—Vehicle to Grid Communication Interface* proposes a standard vehicle-to-grid communication interface
- Open Charge Point Protocol (OCPP) and Open Smart Charging Protocol are communication standards for EV charging stations and network software companies to promote interoperability

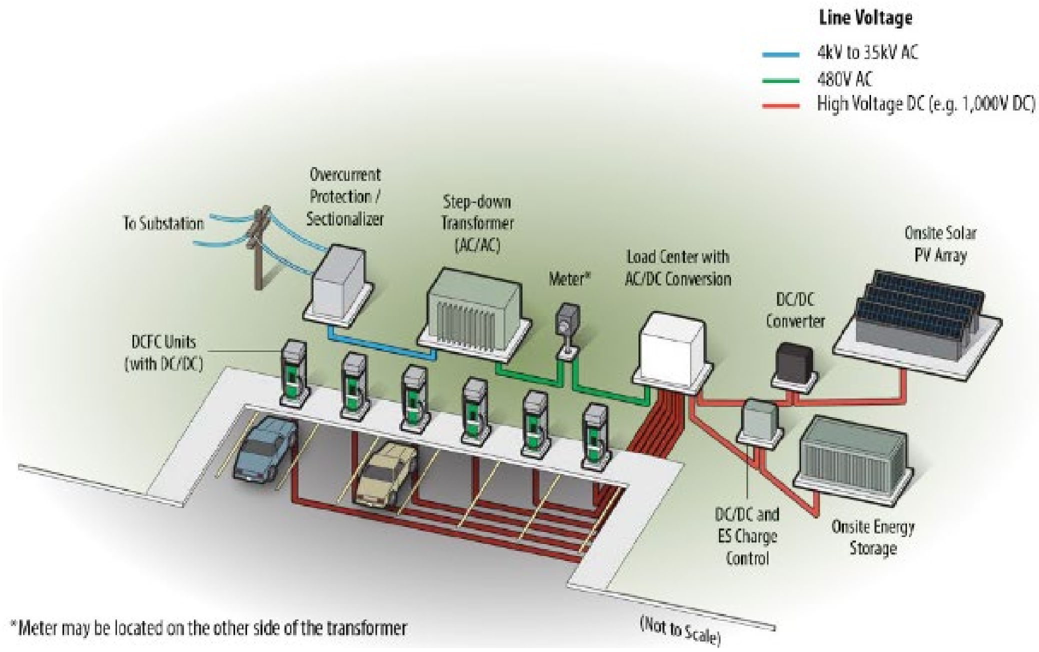
When considering EV chargers on the market, the Port will need to ensure that the EV chargers selected are OCPP-compliant, because these standards are widely adopted and deployed. Jacobs also recommends that the chargers are compliant to OCPP 1.6 as a minimum, which is widely adopted among charge point manufacturers. OCPP is a communication standard for EV charging stations and network software companies. The overarching purpose is that any OCPP-compliant EV charging station can be configured to run on any OCPP-compliant software. This means that the central system can be connected to any charge point, regardless of vendor. In addition, the development of these standards is market driven to meet existing and emergency technology and business requirements (Open Charge Alliance n.d.). A major benefit of using an OCPP-compliant system is the flexibility to choose and change local network providers. This is important because EV networks are still expanding to include new providers, while others exit the market. EV chargers that are OCPP-compliant include some Clipper Creek models, ChargePoint, Enel X, Eaton, Blink, ATOM Power and more. Furthermore, as discussed in the next sections, it is important to select a charging manufacturer with networking capabilities to track usage and status.

F.2.4. EVSE Typical Architectures

DC fast-charging equipment is rapidly evolving to meet the needs of the growing electric industrial and off-highway equipment markets, as well as accommodating the increasing demand for higher power levels to charge vehicles with larger battery packs. Industrial DC charger systems generally come in two different types of system architectures, stand-alone and multi-port, which are described here.

Stand-alone DC chargers are composed of AC-to-DC rectification modules, power electronics, and charging cables/connectors are all housed within the same equipment enclosure cabinet. Typically, the human machine interface (HMI) screen, emergency stop buttons, and other controls are also housed on and within this same enclosure cabinet. This architecture type is typically used in less space-constrained parking areas, smaller vehicle sizes, and lower power levels (for example, from 50 to 150 kW). The stand-alone systems generally are all fed with 480 volt AC input power. Multi-port DC charging systems, also known as "centralized DC rectification," house AC-to-DC rectification modules and some power control electronics in a centralized equipment enclosure located away from the actual vehicle parking areas. High-voltage DC (that is, 1,000-volt DC) cabling is then routed in a standard underground conduit duct bank to several dispensers. Dispensers are typically small pedestals that are placed at the individual parking areas and house the HMI, emergency stop, controls, and cables/connectors. This architecture has many advantages; namely, it provides the charging system with the ability to dynamically shift power in the rectification enclosure to any combination of dispensers, as well as being beneficial when installing systems for large heavy duty equipment as it helps save significant space in a parking area. The centralized architecture systems can typically be purchased with integrated medium-voltage transformers, which allow many systems to accept medium-sized grid voltages ranging from 6 to 34 kV. Figure F-6 from the U.S. Department of Energy illustrates a typica multi-port DCFC site layout.

Figure F-6. Example of a Multi-Port DCFC Complex with Onsite BESS and Solar PV site configuration.



Source: U.S. Department of Energy

F.3 References

Open Charge Alliance (OCA). n.d. Open Charge Point Protocol 1.6. www.openchargealliance.org/protocols/ocpp-16.

Appendix G
Detailed Charger Sizing and Power Recommendations by Vehicle Type

G. Detailed Charger Sizing and Power Recommendations by Vehicle Type

An important next step after determining the fuel and energy usage of the fleet, as well as the electric vehicle (EV) equivalent, is to pair those needs with the adequate EV charger, or electric vehicle supply equipment (EVSE), sizes and power levels. Using the assumption of a 12 hour overnight charge window this section overviews the various charger power levels by each vehicle type and battery pack size to ensure that the vehicles are charged and ready for the next work shift.

G.1 Forklifts and Reach Stackers

Battery electric equivalents for the Port's forklift and reach stacker and/or container handling fleet have somewhat lower duty cycles based on the empirical fuel data collected, and thus, lower charging requirements than other larger container-focused ports. Based on the energy analysis results discussed in Appendix C, the charger speeds shown in Table G1 would be required to replenish the equipment's batteries each night based on operations and duty cycles. The charger power level based on operations (that is, the nominal load) is determined by dividing the daily energy needs of each piece of equipment by the assumed overnight dwell time of 12 hours. From that power level, Jacobs then selected an assumed charger power level based on market-available DC CCS1 charging options that closely aligned with the required charger power levels. This is specific to larger cargo-handling forklifts with a greater than 34,000-pound capacity. There are three smaller forklifts in the 15,000- to 25000-pound capacity range that are assumed to use the Anderson SB-style charger cable connector.

For forklifts, the recommended charger level is greater than the estimated charger power levels. For smaller forklifts using an Anderson SB connector, a Posicharge 80-volt 20-kW charger was selected as the assumed charging system architecture. For the larger forklifts, Jacobs recommends using CCS1 DC connectors based on the 60-kW module architecture of the Power Electronics 1.44-MW NB Station. The assumed Power Electronics configuration is a 60-kW-fed dual-cable dispenser that switches sequentially between two connected vehicles, where the effective charge rate to each vehicle is 30 kW.

Table G-1. Forklift Charger Power Sizing

	Current Equipment			EV Equivalent Charger Sizing	
Building	Asset Type	Manufacturer	Model	Charger Power Level Based on Operations (Nominal Load) (kW)	Recommended Charger Power Level (Maximum Load) (kW)
Warehouse A	Forklift	Kalmar	DCF250-12LB	22	30
	Forklift	Kalmar	DCG250-12LB	22	30
	Forklift	Yale	GDP360	14	30
	Forklift	Hyster	H280X	15	30
	Forklift	Hyster	H280X	15	30
	Forklift	Hyster	H120FT	7	20
	Forklift	Yale	GDP155	9	20
	Forklift	Yale	GDP155	9	20
	Forklift	Hyster	H360HD	15	30
	Forklift	Hyster	H360HD	15	30
	Forklift	Hyster	H360HD	15	30
	Forklift	Hyster	H550HD	24	30

	Current Equipment			EV Equivalent Charger Sizing	
	Forklift	Hyster	H550HD	24	30
	Forklift	Hyster	H550HD	24	30
	Forklift	Hyster	H620HD	24	30
	Forklift	Hyster	H700HD	24	30
	Forklift	Taylor	TE-520M	22	30
	Forklift	Taylor	TH-350L	19	30
	Forklift	Taylor	TX550M	21	30
	Forklift	Taylor	TX550M	21	30
	Forklift	Taylor	X360M	15	30
TOTAL				376	600

Table G-2. Reach Stacker Charger Power Sizing

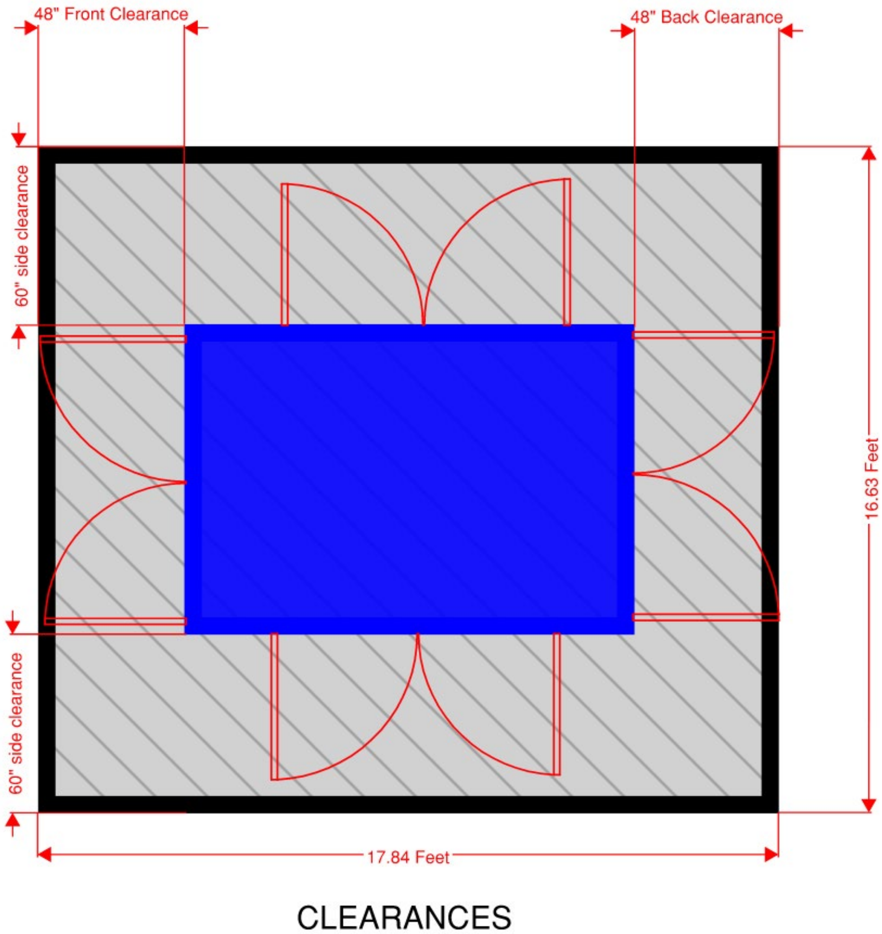
Current Equipment				EV Equivalent Charger Sizing	
Building	**Asset Type**	**Manufacturer**	**Model**	**Charger Power Level Based on Operations (nominal load) (kW)**	**Recommended Charger Power Level (maximum load) (kW)**
Warehouse A	Reach Stacker	Hyster	45-31 CH Series C222	66	120
	Reach Stacker	Hyster	45-31 CH Series D222	66	120
TOTAL				132	240

Power Electronics, an solar inverter and EVSE supplier in the United States, currently produces a 1,440-kW charging system (Figure G-2) that can supply multiple dispensers and dispenser types. This unit can also support 24 plug-in dispensers, with up to 48 CCS1 cables/connectors. The system's design is configurable, allowing for a reduction in the number of dispensers to achieve higher power outputs, with each dispenser capable of reaching a maximum output of 360 kW.

Figure G-2. Power Electronics 1,440 kW Charging System

Source: Power Electronics

Figure G-3. Power Electronics 1,440 kW Charging System Footprint and Clearances



Source: Posicharge

Jacobs Posicharge, a manufacturer of forklift and electric utility vehicle chargers, currently offers a selection of low-voltage battery chargers designed to be compatible with the widely used Anderson SB style connector. Given that the three smaller electric forklift equivalents would be most likely using the 80-volt AC battery architecture and Anderson SB connectors, versus high-voltage lithium-ion batteries and CCS1 connectors of the larger forklifts, Jacobs assumed that the 20-kW SVS-200 charger from Posicharge, shown in Figure G-3, would be accurate for power requirements and charger architecture type.

Figure G-3. Posicharge SVS-200 Charging System

Source: Posicharge

G.2 Yard Tractors

Based on energy analysis results discussed in Appendix C it was determined that the charger speeds listed in Table G-3 would be required to replenish the equipment batteries each night based on operations of the Port's existing yard tractors. The charger power level based on operations (that is, the nominal load) was determined by dividing the daily energy needs of each piece of equipment by the assumed overnight dwell time of 12 hours. From that power level Jacobs then selected an assumed charger power level based on market-available DC CCS1 charging options that closely aligned with the required charger power levels.

Yard tractors, which are exemplified by the BYD 8Y model in the current market, predominantly deploy CCS1 DC connectors that enable charging capacities of up to 120 kW. Taking full advantage of the compact footprint of the Power Electronics 1440kW NB charger system, it was assumed that each yard tractor would have a dedicated dispenser with a single CCS1 cable capable of 60 kW.

Table G-3. Yard Tractor Charger Power Sizing

Current Equipment				EV Equivalent Charger Sizing	
Building	Asset Type	Manufacturer	Model	Charger Power Level Based on Operations (Nominal Load) (kW)	Recommended Charger Power Level (Maximum Load) (kW)
Warehouse A	Yard Spotter	Ottawa	YT50	56	60
	Yard Tractor	Capacity	TJ3000	63	60
	Yard Tractor	Capacity	TJ5000	63	60
TOTAL				182	180

G.3 Rail Locomotive

Jacobs understands that there is a planned design and manufacture of a battery electronic locomotive In Cleveland, for the Port Authority. a battery electric locomotive is being developed by Alternative Motor Power Systems (AMPS) and will be purchased by Omnitrax for use on the Port railway. The locomotive will serve the Port. The locomotive will operate with a battery pack size of 1.4 MWh and a nominal battery pack voltage of 750-volt DC and a CCS1 charge port capability of 350A, allowing a theoretical maximum charge rate of 240 kW via CCS1 plug-in cable connector. The overnight charging window for the locomotive is anticipated to be 12 hours. Jacobs also assumed that, through the course of a normal operating day, the locomotive would expend 80% of its battery capacity between 7 a.m. and 4 p.m. daily (9 hours), requiring 1,120 kWh to be replenished each night. Across the charging overnight period of 12 hours, this would equate to an average charge rate of 93 kW to meet the operational demand. Given that the majority of DC chargers on the market ramp up and down across a charging curve dictated by the locomotive battery management system, Jacobs recommends installing chargers that are slightly oversized to ensure that operational needs are adequately buffered and met.

DC charger systems capable of providing 240 kW or greater were selected as the assumed charger architectures for the Port's rail locomotives. Jacobs products on the market and found the most suitable options to be either new systems from Heliox, the Flex 360 model, shown in Figure G-4, and ABB's HVC360, shown in Figure G-5. These units have DC power modules that can provide charging power ranging from 60 to 360 kW depending on the vehicle and equipment type, as well as that vehicle's charge port amperage limitations.

Given the low duty cycles of the locomotive, these chargers would typically stand idle during a normal workday, and Jacobs recommends making these chargers and dispensers available for mid-day fast-charging of the cargo-handling equipment fleet. This would be especially important during days where loading/unloading operations were operating additional or overtime hours.

Figure G-4. Heliox Flex 360

Source: Heliox

Figure G-5. ABB HVC360

Source: ABB

Jacobs' recommended charging architecture configuration is one that can provide up to 240 kW of DC charger power via a 350A CCS1 connector, which would replenish the vehicle in less than 5 hours. The charger pedestals would use CCS1 connectors in the short term, but potentially could accommodate MCS and J3105 connector types in the future to allow for power transfer at a rate up to 360 kW depending on the locomotive procured. Table G-4 illustrates the recommended charger power level and size.

Table G-4. Locomotive Charger Power Sizing

Current Equipment				EV Equivalent Charger Sizing	
Building	Asset Type	Manufacturer	Model	Charger Power Level Based on Operations (Nominal Load) (kW)	Recommended Charger Power Level (Maximum Load) (kW)
Warehouse A	Switching Locomotive	General Motors	GP9	505	360
TOTAL				240*	360

Note: Locomotive being procured is currently limited to approximately 240 kW due to the CCS1 connector type and Port limitations.

G.4 Payloader

The energy analysis conducted in Appendix C determined necessary charger speeds essential for nightly battery replenishment of Port equipment. This determination was based on continuous operation of the Port's existing payloader (also known as a front-end loader) over an 8-hour period. The determination of charger power level, tailored to operational requirements (that is, the nominal load), involves dividing the daily energy demands of individual equipment units by the presumed 12-hour overnight dwell time. This yields a charger power level requirement of 100 kW to replenish the 1197 kWh daily requirement, a substantial energy demand.

Given that the payloader had 28 operating hours annually in 2022, Jacobs assumed that a full 8-hour operating day was not typical, and that equipment would operate at an average of 1.2 hours per week. Battery electric and hydrogen versions of heavy earthmoving construction equipment such as payloaders are scarce in the current market and are considered more difficult to transition to zero-emission. Table G-5 illustrates the recommended charger power level and size.

As of 2023, one payloader is commercially available, the LiuGong 856HE which uses a 432-kWh battery paired with a CCS1 DC connector and the ability to charge up to approximately 150 kW. To charge the HEVI Gel-5000 over 12 hours, a charger power level of 23 kW is required. This plan assumes a charger dispenser power level of 30 kW would be sufficient for the Port's payloader. Jacobs assumed that the payloader will share a dual-cable 60-kW dispenser with a forklift and charge via DC high-voltage power provided from the 1440-kW Power Electronics NB Station.

Table G-5. Payloader Charger Power Sizing

Current Equipment				EV Equivalent Charger Sizing	
Building	Asset Type	Manufacturer	Model	Charger Power Level Based on Operations (Nominal Load) (kW)	Recommended Charger Power Level (Maximum Load) (kW)
Warehouse A	Payloader	Volvo	L180H	100	30
TOTAL				100	30

G.5 Light-Duty Trucks, SUVs, and Other Support Equipment

The Port utilizes a small number of light-duty trucks and SUVs alongside support equipment such as a diesel generator and manlifts for maintenance and administration activities in and around the Port facility. The energy analysis conducted in Appendix C determined the charger speeds for nightly battery replenishment of pickup trucks, SUVs, UTVs, manlifts, generator and sweeper. The determination of charger power level was tailored to operational requirements (that is, the nominal load), and involved dividing the daily energy demands of individual equipment units by the presumed 12-hour overnight dwell time. Across the set of vehicles, analysis determined that UTVs have maximum daily kWh, equating to 161 kWh where the minimum charge rate was 13 kW.

Given the Port's operations and available charge points, Jacobs suggests using Level 2 AC chargers with a 19.2-kW capacity per socket. For the Port, Jacobs proposes using four ChargePoint CP6000 units or equivalent Blink IQ200 charge points. Three units should be placed at Warehouse 26 to serve light-duty trucks, SUVs, and UTVs, while one unit should be positioned at Warehouse A for support equipment (that is, the generator, manlifts, and sweeper). Both ChargePoint CP6000 and Blink IQ200 offer a variety of advanced features such as remote monitoring and scheduling. These features can optimize the charging infrastructure and ensure that Port fleet vehicles are always charged and ready to operate. Jacobs recommends using only one charge point manufacturer for continuity and seamless integration across Port operations through software management. Mixing and matching different charge point models can lead to compatibility issues and performance problems.

Jacobs' recommendation for implementing charge points for SUVs pickups and UTVs is based on the specific use cases of these vehicles. The light-duty trucks primarily serve local transportation needs within various Port facilities, which includes maintenance tasks and visitor tours, as well as regional travel within a range of up to 250 miles. A 19.2-kW charge point offers sufficient charging capacity to meet daily local usage demands of these trucks, where commercially available BEVs that can charge up to 19.2 kW are abundant. Additionally, for regional travel up to 250 miles away, trucks can rely on fast-charging stations available along their routes, eliminating the need for an exceptionally high-capacity charge point at the Port. These vehicles, with or without regular return to the terminal, can use downtime for recharging, ensuring continuous availability for daily operational, maintenance, and tour-related activities. Jacobs also determined that the maximum annual energy demand for the generator is 326 kWh and that he manlifts require 2,492 kWh. Given these comparatively minor energy requirements, the electrified replacements can be served by a single CP6000 unit, configured to deliver 19.2 kW per charge port in the event the Port's operations unexpectedly increase. Table G-6 illustrates the recommended charger power level and size.

Table G-6. Light-Duty Vehicles and UTVs

Current Equipment				EV Equivalent Charger Sizing	
Building	Asset Type	Manufacturer	Model	Charger Power Level Based on Operations (Nominal Load) (kW)	Recommended Charger Power Level (Maximum Load) (kW)
Warehouse 26	Pickup	Chevy	Colorado	5	19.2
	Pickup	Ford	F250	5	19.2
	Pickup	Ford	F350	5	19.2
	SUV	Ford	Explorer	5	19.2
	SUV	Ford	Explorer	5	19.2
	UTV	Bobcat	UW56	13	19.2
	UTV	Polaris	Brutus HD	6	19.2
TOTAL				44	134.4

Table G-7 shows analysis outcomes for Port support equipment, including one generator, two manlifts and one sweeper where Jacobs applied the same methodology to determine the charger power level (the nominal load) to determine recommended charging infrastructure. Table G-7 illustrates the recommended charger power level and size.

Table G-7. Support Equipment

Current Equipment				EV Equivalent Charger Sizing	
Building	Asset Type	Manufacturer	Model	Charger Power Level Based on Operations (Nominal Load) (kW)	Recommended Charger Power Level (Maximum Load) (kW)
Warehouse A	Generator	Kubota	GL14000	5	7
	Man Lift	Snorkel	TB80	11	10
	Man Lift	Snorkel	TB60	11	10
	Sweeper	Tennant	8410	NA	7
TOTAL				27	34

G.6 Work Barges

The electric vessel market is in its infancy; rapid change in vessel propulsion systems and associated infrastructure are likely. For example, hydrofoil systems, lift electric-powered boats above water, cutting noise, drag, and costs. While mainly used for recreation now, electric-hydrofoil boats could soon be applied in commercial workboats.

Table G-8 specifies the charger speeds needed to recharge the Port's work barge batteries every night. The charger power level for operations (that is, the nominal load) is calculated by dividing each equipment's daily energy needs by the assumed 12-hour overnight dwell time. Jacobs then selected an appropriate charger power level from available DC CCS1 charging options that matched required power levels. Table G-8 illustrates the recommended charger power level and size.

Table G-8. Work Barge Charger Power Sizing

Current Equipment				EV Equivalent Charger Sizing	
Building	Asset Type	Manufacturer	Model	Charger Power Level Based on Operations (Nominal Load) (kW)	Recommended Charger Power Level (Maximum Load) (kW)
Offsite Dock Area	Work Barge	-	25' Lake Assault	43	75
	Work Barge	-	25' Lake Assault	43	75
TOTAL				86	150

Electrified boats and vocational vessels in North America typically use CCS1 DC connectors. This niche industry is rapidly growing, and adoption is expected to increase exponentially in the next 5 years. Work barges, due to their size and use case, are excellent candidates for retrofitting with electric propulsion and battery systems. The Tritium RTM75 charger, widely used for electric vessels and boats, stands out for its popularity. Its liquid-cooling (not air-cooling dependent) enables an IP65 rating and a stainless-steel enclosure, an ideal candidate for corrosive and wet environments. It is recommended that the Port of Cleveland install two systems similar to the Tritium RTM75 dockside at the Edgewater Marina where the work barges are currently docked. An example of a Tritium charger is shown in Figure G-6.

Figure G-6. Tritium RTM75

Source: Aqua superPower

Appendix H
Cold Ironing Call and Energy Analysis

H. Cold Ironing Call and Energy Analysis

To develop an accurate and grounded conclusion on cold ironing energy needs, it was important to analyze the existing port call list and categorize the ship classes and types into multiple categories that energy consumption assumptions can be paired with. This section overviews the call and energy analysis for Port of Cleveland's (Port's) cold ironing needs.

H.1 Calling Fleet Analysis

To help Jacobs perform a calling fleet analysis, the Port provided a summary of port calls listing the vessels, the berth at which they called, the arrival time, and the departure time from the berth. The summary of port calls also included information about the commodities that were loaded or unloaded.

The Port provided a summary of port calls for 2019–2022 for the main piers, while a listing of bulk terminal calls was provided for 2022; 523 distinct vessel calls were compiled. According to this summary of port calls, there are 31 operators that have made at least one call, with 19 vessels having made 5 or more calls over this time period. A total of 152 unique self-powered vessels and 8 unique towed barges have called at the Port. Table H-1 lists the operators, number of operator vessels who have called at the Port, and the total number of port calls.

Table H-1. 2022 Port of Cleveland Call List

Operator	Number of Vessels	Number of Calls
American Steamship	10	125
Fednav	43	82
Wagenborg Shipping	14	61
Polish Steamship Co	13	32
Spliethoff	13	28
American Queen Voyages	2	28
Interlake Steamship	5	24
Decommissioned	1	23
Grand River Navigation	2	15
VanEnkevort Tug & Barge	3	13
BBC Chartering	12	10
McKeil Marine	4	12
Unifeeder	1	11
Algoma Central Corp	8	9
BigLift Shipping	3	8
Oldendorff Carriers	2	6
Vantage Deluxe	1	6
Canadian Forest Navigation	4	5
Rand Logistics	2	5
NEAS Group	2	4
Central Marine	2	3
Arab Bridge Maritime	1	2
Carsten Rehder	1	2
NEAS Inc	1	2

Operator	Number of Vessels	Number of Calls
Combi Lift K/S	1	1
Dauelsberg, Herm	1	1
FrontMarine	1	1
Lower Lakes Towing	1	1
Pearl Seas Cruises	1	1
Seaway Marine	1	1
Sunship Schiff	1	1

H.2 Power Requirements

When a vessel is connected to shore power, most of the vessel's electrical systems are powered through shore power. This is called a hoteling load. Hoteling load power requirements vary based on the type of vessel and the demands of its onboard electrical systems. For example. if shipboard cargo-handling equipment is used during loading and unloading operations, those operations would need to be powered via the shore power system. If a cruise ship is connected to shore power, the hoteling load can be very large; the ship requires power for myriad electrical systems on board. The complexity of cruise ship systems is high compared to most cargo vessels.

The hoteling load for a vessel includes what is required to support the vessel's electrical system. These typically include power required for lighting, heating, ventilation and air-conditioning (HVAC), galley operations, communications, radar, pumps, water heating and other auxiliary loads. In some instances, this load will also include the power required for a vessel's loading and unloading gear such as cranes, augers, and conveyors. These loads may vary based on how many crew or passengers may be on board the vessel.

To determine the upper bounds of power and energy requirements for a shore power system, an estimate of shore power demands for each vessel must be determined. Table H-2 shows how demands vary based on vessel type and size.

Table H-2. Hoteling Load by Vessel Type

Vessel Type	Vessel Class Name	Hoteling (kW)
Bulk Carrier	Small Handy	280
Bulk Carrier	Mid Handy	280
Bulk Carrier	Handymax	370
Bulk Carrier	Panamax	600
Bulk Carrier	Lake Freighter (Capemax)	600
Cruise	Cruise < 2000 DWT	450*
Cruise	Cruise < 10000 DWT	2450*
Barge	Barge	200
Tug	Tug	50

Note: Hoteling load here is calculated from the total installed power x the hoteling load factor per Corbett and Comer 2013.

For planning purposes, a typical power demand per vessel was used as opposed to an exact usage of each vessel as the demand may vary ship to ship and the development of power profiles for each calling vessel is beyond the scope of this study. At this stage, the use of industry standard demands and estimates is appropriate.

The US Environmental Protection Agency (EPA) has published hoteling load shore power estimates by vessel class designation in their Shore Power Emissions Calculator.[3] Hoteling loads shown in Table H-2 are computed using methodologies from EPA's *Ports Emissions Inventory Guidance: Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions Report* (EPA 2022).

Overall energy demand for each vessel call was calculated using the estimated power demands shown in Table H-2. As described previously, the raw data included calls from 2019–2022. Also, 2022 was the only year in which calls to the bulk terminal were known and included in the overall data set. To perform an analysis that represents a full year of calls, the 2022 data were used to generate the monthly anticipated energy demand and energy demand by berth number. To ensure the data provide a complete picture of demand, some adjustments to data were made.

Bulk terminal call information included the vessel's date of call and the name. The exact durations of these calls were not recorded. The Port provided a call record with adjusted durations. These calls had two specific durations, a 5.5 hour call for an unloading vessel and an 8 hour call for loading. These durations are included in the analysis.

Viking's cruise ship *Polaris* has begun calling at the Port and will likely average eight calls per year. An additional eight calls were added to the 2022 to simulate the *Polaris*' assumed schedule in future years. These calls were spaced out at once per month from March to October.

H.3 Vessel Implementation Timeline

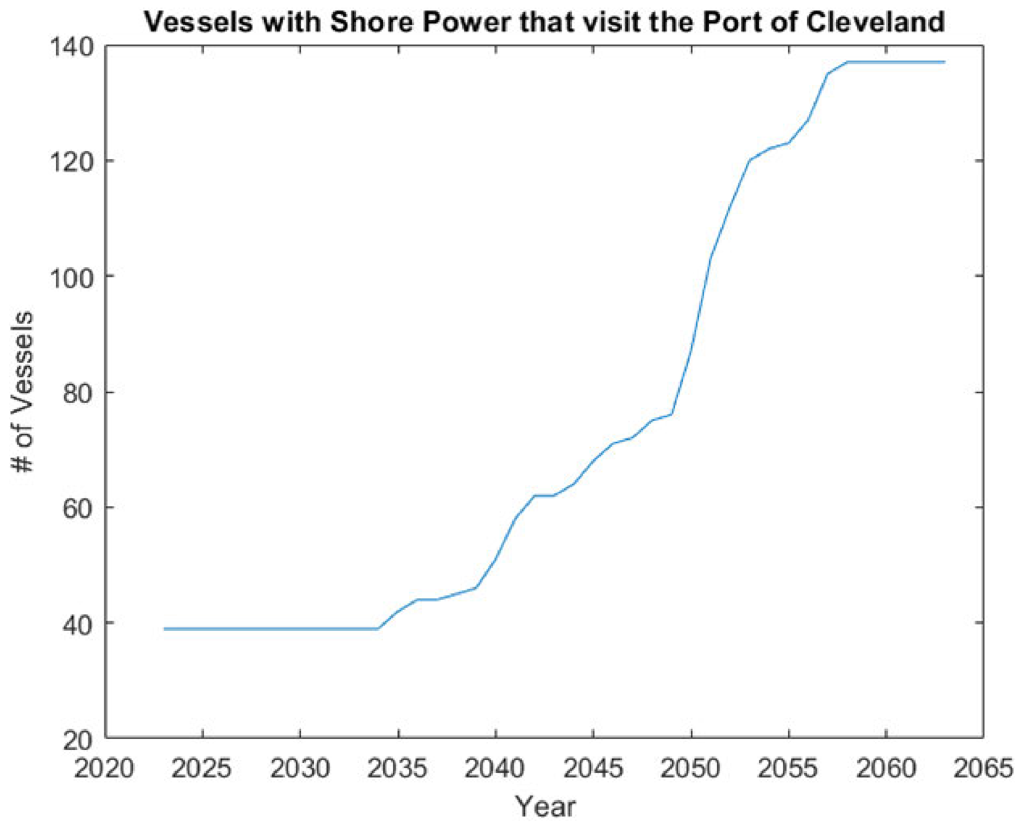
Based on the age of the vessels calling at the Port, few were constructed with shore power connections. With the passage of the FuelEU maritime initiative however, use of shore power in many larger European ports is mandated beginning in 2030. While FuelEU legislation is particular to Europe, this signals an overall trend in the industry to allow vessels to connect to shore power. Not all ports will require this in the future, but vessels that may trade in European Union ports are beginning to develop shore power capabilities. Older vessels with considerable useful life remaining may retrofit these capabilities. However, most shore power capabilities will be incorporated into newly built vessels.

It is anticipated that vessels calling at the Port will begin a transition to shore power connection as vessels aged and retire. The average operational life of a cargo vessel is approximately 30 years. For the purposes of this planning effort it was assumed that, as these vessels reach the end of their useful life, they will be replaced with a new vessel that has shore power capabilities.

For this study, an analysis was performed that looked at the current age of the fleet and modeled the gradual replacement of vessels as they retire. The goal was to understand how shore power demands would grow over time. For this analysis the overall size of the fleet was assumed to be static, but the percentage of ships with shore power capabilities was assumed to increase over time. The analysis was based on the assumption that any vessel constructed after 2018 would have shore power capabilities. Figure H-1 is a graphical representation of vessels calling at the Port who will transition to shore power readiness.

[3] https://www.epa.gov/ports-initiative/shore-power-technology-assessment-us-ports

Figure H-1. Anticipated Cold Ironing Capable Vessel Adoption



H.4 References

US Environmental Protection Agency (EPA). 2022. *Ports Emissions Inventory Guidance: Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions.* Document ID EPA-420-B-22-011. April. https://www.epa.gov/state-and-local-transportation/port-emissions-inventory-guidance.

Corbett and Comer, 2013. *The Shore Power and Diesel Emissions Model*

Appendix I
Cold Ironing Technologies, Methods, Suppliers, and Equipment

I. Cold Ironing Technologies, Methods, Suppliers, and Equipment

Equally integral to the estimation of power requirements is the method at which the power is transferred from the shore to vessel. Flexibility to accommodate multiple vessel types for decades to come should be considered, and there are a variety of innovative products on the market that can help ensure that flexibility. This appendix will give an overview of the recommended cable management product and system types available, as well as their strengths and weaknesses.

I.1 Existing Infrastructure

As part of the 2021 Dock 24 & 26 Master Modernization & Rehabilitation Project (Johnson, Mirriam, and Thompson (JMT) 2021) concrete encased duct banks and utility manholes were installed along the berths at Dock 24 and 26. The duct banks are each composed of six 5-inch diameter Schedule 40 polyvinyl chloride (PVC) conduits. Typically, two manholes are installed per berth, one near the waterside end of the berth, one at mid berth. Berth 26E is planned to be rehabilitated in the future, with dock widening and strengthening to support heavy lift operations and the expansion of the rail lines down the dock. As such, the conduit run was capped approximately 70 feet down the dock. All of the conduit banks run to a singular 8-foot by 8-foot utility vault located to the north of Warehouse A.

I.2 Dockside Power Cable Management Technologies and Considerations

Cold ironing or shore power systems are commonly referred to as high voltage shore connections (HVSCs). A shore power system itself has several components that each have a unique purpose. A shore power system originates with high-voltage power distributed from the power provider, or utility. This high-voltage power is transmitted to a substation, and is then transmitted from the substation switchgear to feed the Port of Cleveland (Port). The high-voltage feed will terminate at a point near Warehouse A. The existing shore power feed duct banks all converge at this point.

High-voltage power from the utility feeds though a stepdown transformer and switchgear to convert the power to a 6.6-volt, 3-phase power at 60 hertz (Hz). From that point, the power is distributed along the berth to manholes, where a portable cable management system (CMS) connects to the feed. The cables from the CMS will connect to the vessel in the berth and provide shore power. Each berth will require a separate stepdown transformer and CMS to complete the system, as the international standard governing the system design allows for only one ship to be connected to the HVSC transformer at a time.

The components of the system are designed in accordance with International Electrotechnical Commission (IEC)/Institute of Electrical and Electronics Engineers (IEEE) Standard 80005-1:2019, which is an international design standard for HVSCss. This standard lays the groundwork for standardization of shore power systems globally, allowing for maximum interoperability among ship- and shore-based systems. IEC/IEEE 80005-1:2019 provides guidance for developing systems ranging from hardware requirements to operations methodologies.

All vendors that operate in the shore power industry who will offer products and designs must comply with IEC/IEEE 80005-1:2019. Table I-1 is a list of vendors who provide both switchgear and CMS systemsas shown in Figures I-1 through I-8.

Table I-1. Shore Power Equipment Providers

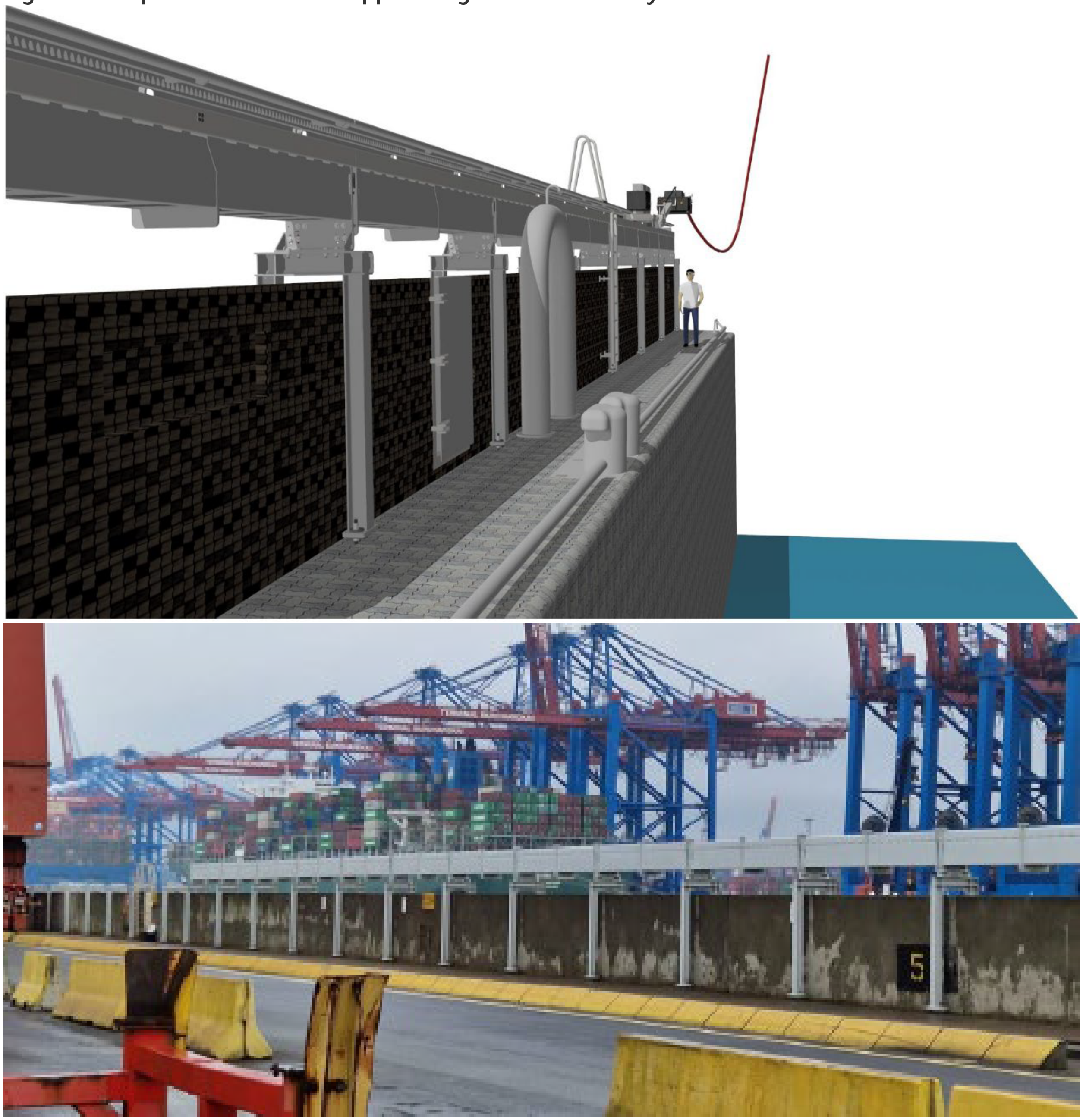
Vendor	Switchgear and Controls	Cable Management Systems
Wabtech/Stemmann-Technik		X
Cavotec	X	X

Vendor	Switchgear and Controls	Cable Management Systems
Powercon	X	X
ABB	X	
Igus		X
Siemens	X	X
Schneider Electric	X	
Shore Link		X

Figure I-1. Quayside Face Mounted Igus Shore Power System

Source: Ingus Shorepower Systems

Figure I-2. Top Mount Structure Supported Igus Shore Power System



Source: Ingus Shorepower Systems

Figure I-3. Igus Reel Shore Power System

Source: Ingus

Figure I-4. Cavotec Mobile Reel Shore Power System

Source: Cavotec

Figure I-5. Fixed and Repositionable Crane Cable Management System

Source: Cavotec

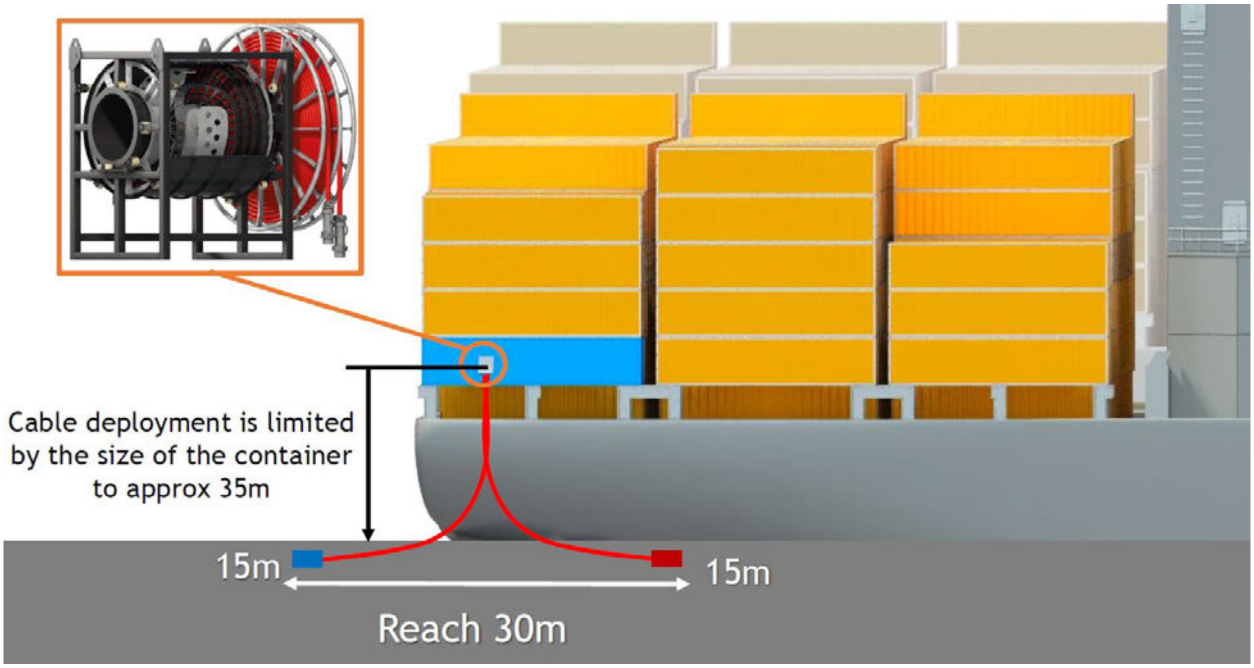
Figure I-6. Example Below Grade Electrical Vault

Source: Cavotec

Figure I-7. Example Above Grade Electrical Connection

Source: Cavotec

Figure I-8. Vessel Based Cable Management



Source: Cavotec

I.3 References

Johnson, Mirriam, and Thompson (JMT) 2021. 2021 *Dock 24 & 26 Master Modernization & Rehabilitation Project Construction Drawings*

Appendix J
Warehouse Condition Assessment and Observation Report

Cleveland-Cuyahoga County Port Authority

ELECTRIFICATION AND WAREHOUSE A MODERNIZATION PROJECT

775 Erieside Avenue, Cleveland, Ohio 44113

CIVIL, ARCHITECTURAL, STRUCTURAL, HVAC, ELECTRICAL
Condition Assessment of Warehouse A

Presented by:

OSBORN ENGINEERING

Jacobs

Contents

Introduction

The objectives of this project are the development of a detailed electrification and net zero emissions master plan for the General Cargo Terminal, aggregation and collection of project input data and existing conditions, establishment of the project basemap with existing grades/topography, performance of necessary testing/field verification, development of the basis of design, and updating of the preliminary Project estimate.

A critical sub-element of this phase of the Project will be coordination with Cleveland Public Power on the future power requirements/needs of the Port Authority's General Cargo Terminal, which are projected to substantially increase as portions of the Terminal's operations are electrified. [redacted]

Existing Condition assessments as described within this Report were concentrated at the Warehouse A and the surrounding site. The assessment is focused on elements directly affected by the anticipated scope of the Warehouse Rehabilitation project. All site assessments completed to construct this Condition Assessment Report were visual in nature. Visual observations were limited to accessible areas and elements not covered by obstructions.

Section 1. Condition Assessment Approach

1.1. Project Summary

1.1.1. Extents of the Project

This report is a general visual condition assessment of Cleveland-Cuyahoga County Port Authority Warehouse A and it's surrounding area. The items reviewed were site civil, architectural elements, structural, including floor slab and electrical.

1.1.2. Architectural Approach

The scope of the Architectural Condition Assessment focuses on individual building components of Warehouse A and areas where work is anticipated as part of this project. This assessment covers the building envelope including exterior walls, doors, and windows. The roof is not readily accessible and has not been reviewed as part of this assessment, however, the roof was previously assessed and found to be in poor condition. The interior assessment covers the main warehouse area including wall and the underside of the roof. The floor is a structural slab and has been included in the structural assessment.

1.1.3. Structural Approach

The scope of the Structural Condition Assessment focuses on building framing elements of Warehouse A. This assessment covers the structural steel framing, including building columns, bracing, roof trusses, purlins, girts, crane columns, crane girders and rails. The assessment also includes the existing structural concrete slab on grade and loading dock concrete.

1.1.4. Civil Approach

The focus of the civil condition assessments is on any changes made to the civil infrastructure outside the affected buildings, which may include modifications to site access, utilities such as water, sewer, and storm, pavement, and changes to drainage. The review also ensures compliance with the current Water Quality Master Plan (WQMP) dated January 2022, local sanitary/water regulations, and ADA standards.

1.1.5. Plumbing Approach

The Plumbing Condition Assessment focuses on individual building systems to the extent they will be affected by this project. This assessment covers potable water, sanitary drain-waste-vent, and storm drain systems. Age and condition of individual components, and compliance with the Ohio Plumbing Code for whole systems has been reviewed.

1.1.6. HVAC Approach

The HVAC Condition Assessment reviews existing heating, ventilating, and air conditioning (where applicable) at each of the buildings against new ventilation and temperature requirements of the spaces. Existing HVAC compliance with Ohio Mechanical Code and equipment age are reviewed, replacement recommended where necessary.

1.1.7. Electrical Approach

The scope of the Electrical Condition Assessment focuses on site utilities to Warehouse A, power distribution, exterior and interior lighting, emergency lights and exit signs, and the fire alarm system. This included a look at the electrical service to the overhead cranes, how site lighting is served from Warehouse A. Most importantly, each electrical system was reviewed for its ability to be reused in a remodel and put into service for another thirty years. In most cases, equipment is at or beyond its normal rated life, shows signs of degradation due to being in an unconditioned space, and with a few exceptions (exterior LED lighting, possibly the overhead busway), most components will require replacement in the upcoming renovation.

Section 2. Warehouse A Assessment

2.1. Architectural Elements

Warehouse A was constructed in 1975, and most elements appear to be original to the building. The warehouse exterior walls are constructed with an abuse wall to 7-feet above finished floor, with the remainder of the wall being metal panel. On the east, west and south walls a translucent panel clerestory is provided at the top of the wall to allow for some natural light. The roof is a structural standing seam metal roof. Support spaces including an office and sprinkler rooms are attached to the main warehouse and are constructed of CMU. Most of these elements are approach 50-year old and at the end of their useful life.

2.1.1. Exterior Enclosure

2.1.1.1. Exterior Walls

The exterior walls of the warehouse have cast-in-place concrete abuse wall extending to approximately 7-foot above the interior finished floor around the entire perimeter of the warehouse. The remainder of the wall above abuse wall is a ribbed metal wall panel on steel girts. Batt insulation with a facer sheet is installed and exposed on the interior of the building. The Office block and the (3) sprinkler rooms that are attached to the main warehouse exterior walls are exposed CMU with a painted finish.

The concrete abuse wall at the base of the warehouse was found to be in fair to good condition showing normal wear and tear expected for the age. There were a few location where the wall has vertical cracking likely due to some differential settlement (Photos 2.1.1.1.1-2-3). These cracks should be routed out and cracks repaired. There was one location where the cracking occurred and a large spalled section of concrete exists (Photo 2.1.1.1.4). This occurred immediately adjacent to an overhead door opening and may have been a combination of a crack caused by settlement and impact damage. This area will need the cracks repaired and the spalled area patched. Once the crack and damaged areas of the wall are repaired, it is recommended to coat the entire concrete wall with an elastomeric coating that is able to bridge hairline cracking, and will conceal the repairs and restore the appearance of the wall to a like-new condition.

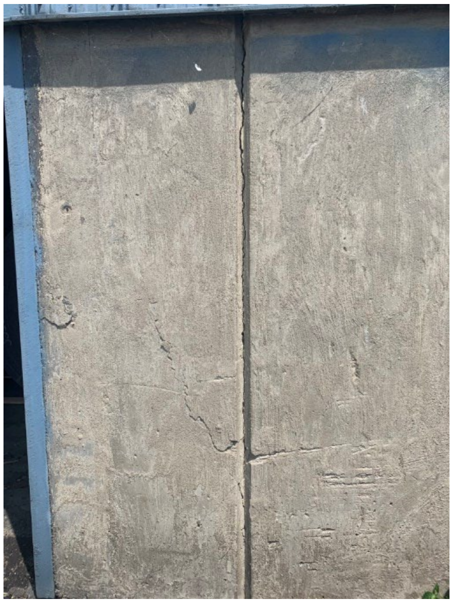


Photo 2.1.1.1.1 Vertical crack located at the control joint. Other minor cracking each side of the joint. Cracks should be routed out and repaired.

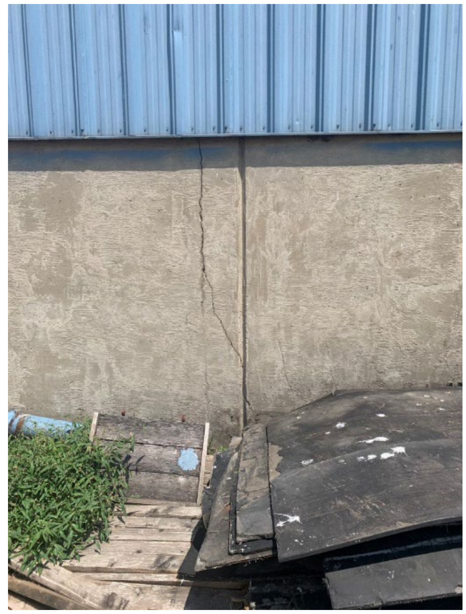


Photo 2.1.1.1.1 Vertical crack in the abuse wall.. Cracks should be routed out and repaired.

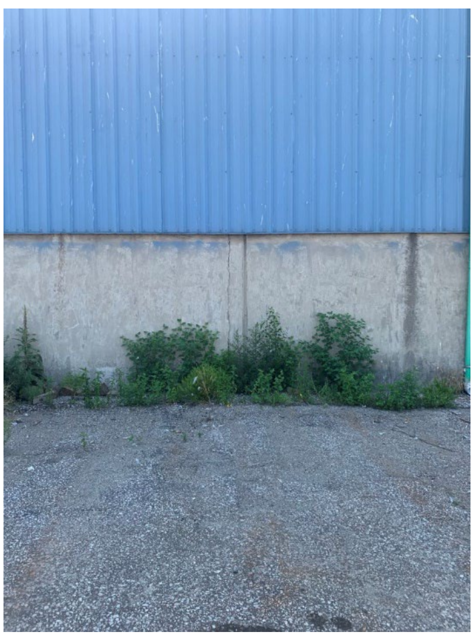


Photo 2.1.1.1.3 Vertical crack located approximately 6-inches away from control joint. Cracks should be routed out and repaired.

Photo 2.1.1.1.4 Vertical crack and large spalled area. Possible caused by a combination of differential settlement and impact damage.

The existing metal wall panels have a ribbed profile and are attached to the girts with exposed fasteners. The wall panels are generally in poor condition. They are original to the building and have faded considerable and have differential coloration appearing heavily worn (Photos 2.1.1.1.5). The panels have also been damaged with holes, tears and dents found around the entire perimeter of the building (Photos 2.1.1.1.6-7-8). In addition, the metal trim around openings has been damaged (Photos 2.1.1.1.9 and 2.1.1.1.10).

Photo 2.1.1.1.5 Existing metal siding is faded and has differently coloration and staining.

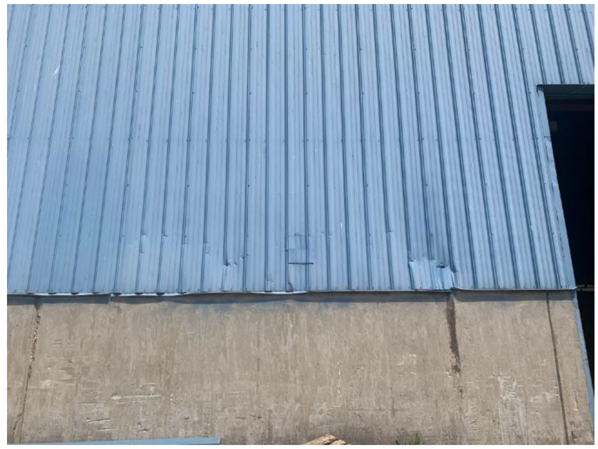


Photo 2.1.1.1.6 Damaged metal wall panels with dents and holes.

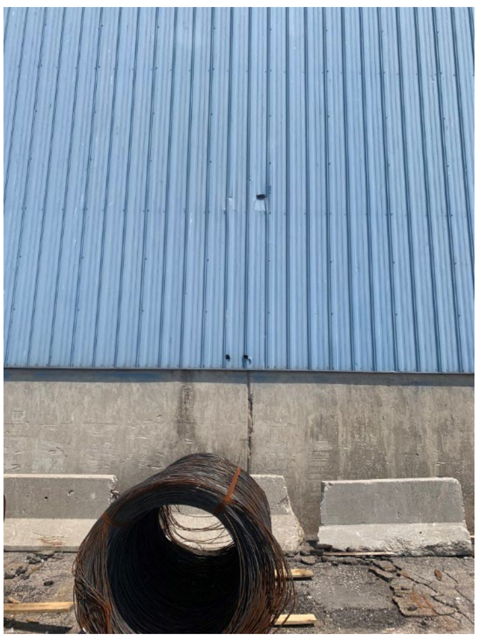


Photo 2.1.1.1.7 Hole in metal wall panel.

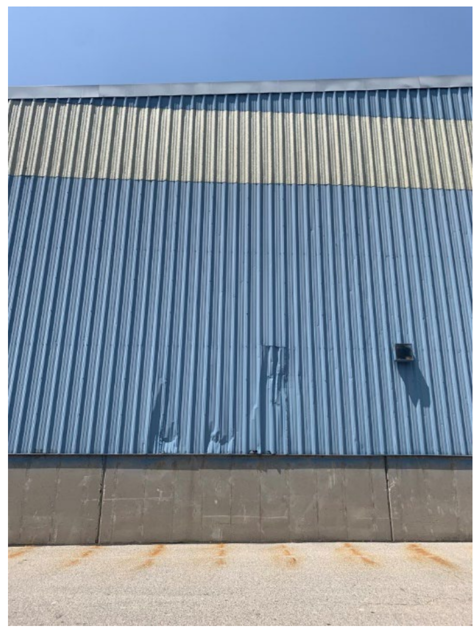


Photo 2.1.1.1.8 Damaged metal wall panels with dents and holes.

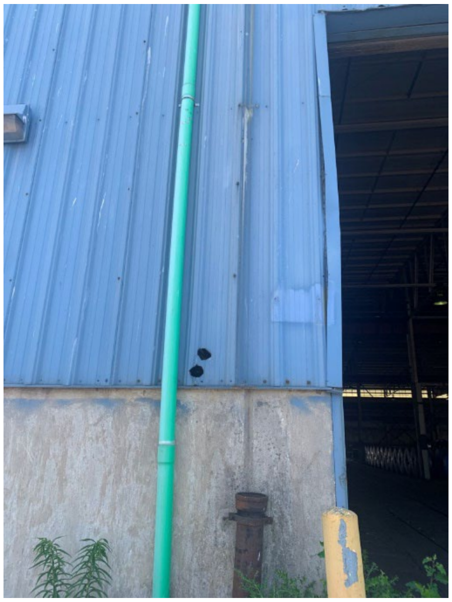


Photo 2.1.1.1.9 Damaged trim at jamb of overhead door.

Photo 2.1.1.1.10 Damaged trim and metal wall panel at the head of the overhead door.

The exterior walls of the Office block is constructed of CMU and is in fair condition. There are portions of the CMU wall where the block is heavily weather, and the CMU is deteriorating and will need to be replaced. Portions of the field will also need to be tuckpointed where the mortar joints have begun to deteriorate and deeper than the adjacent joints. The other area of the wall that is in poor condition is the lintels over the doors and windows where they are failing and will need to be replaced. The paint coating on the wall is in good condition with some fading but remains intact and does not have any peeling or blistering.

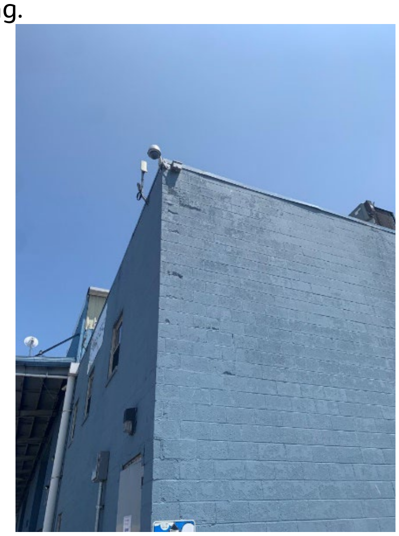


Photo 2.1.1.1.11 Heavily weathered CMU and mortar joints at the corner will need to be replaced. There are other areas in the CMU wall where the mortar joints will need to be tuckpointed.

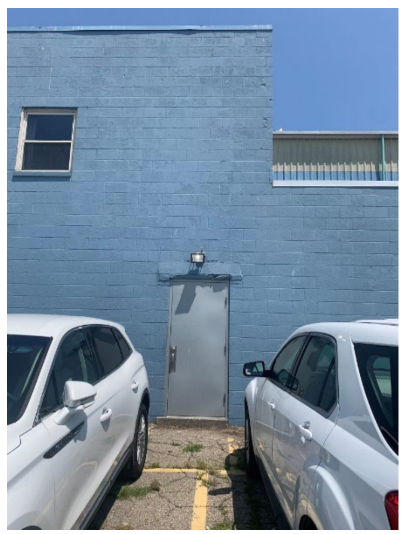


Photo 2.1.1.1.12 Lintel over the door has failed and will need to be replaced..

Photo 2.1.1.1.13 Lintel over the door is failing and will need to be replaced. Mortar joints around the lintel will need to be tuckpointed.

Photo 2.1.1.1.14 Mortar joints in the wall are worn and will need to be tuckpointed.

The electrical substation is constructed with CMU walls is in fair condition. There are several areas where the CMU is heavily weathered where the blocks will need to be replaced. Tuckpoint will also be required in several areas as well. The lintels over door openings will also need to be replaced and the step cracking repaired. There are areas where the paint coatings have failed and are pealing and will need to be repainted.

Photo 2.1.1.1.15 Areas of the CMU wall is heavily weathered and will need to be replaced. Lintels over the doors have started to fail and will need to be replaced and step cracking emanating from the corner will need to be repaired.

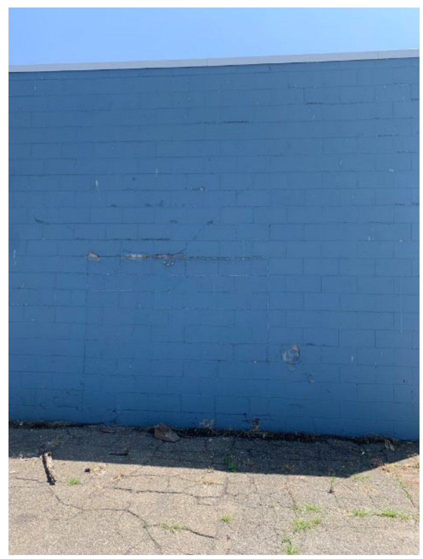


Photo 2.1.1.1.16 Areas of the CMU wall have failed mortar joints and will need to be tuckpointed. The paint coating has also failed and is pealing.

The three sprinkler rooms are constructed with CMU walls and in varying conditions. The north most sprinkler room is in poor condition with significant deterioration of the CMU and need to be reconstructed. The central and southern sprinkler rooms are in fair condition and will require some minor repairs and tuckpoint. The coatings on these two sprinkler rooms appear to be faded, but well adhered, and should have a new elastomeric coating applied once repairs are completed.

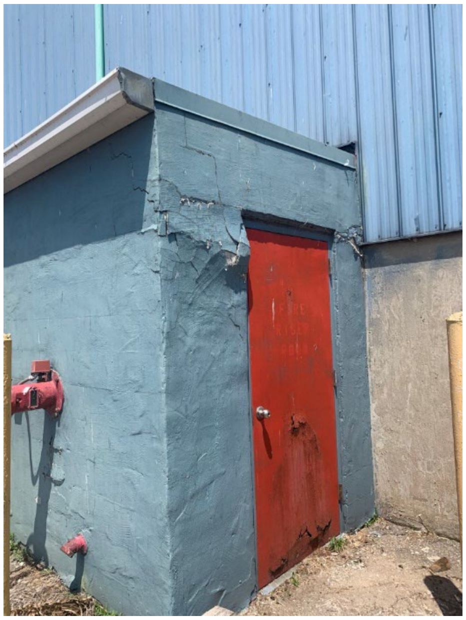


Photo 2.1.1.1.17 Northern Sprinkler roof CMU is in poor condition and has failed. The entire sprinkler room will need to be reconstructed.

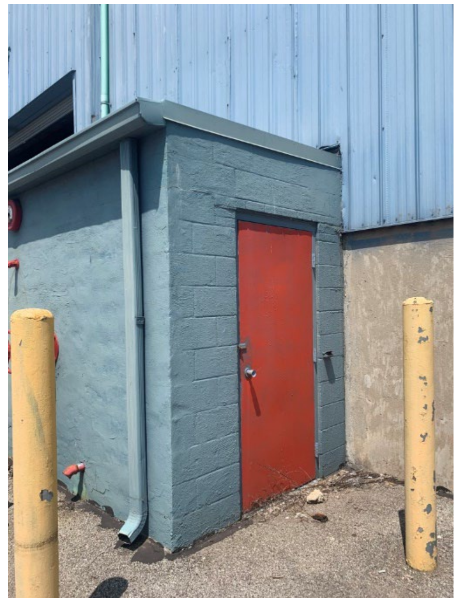


Photo 2.1.1.1.18 The central and southern sprinkler rooms are in fair condition and will require some minor masonry repair and tuckpointing of the mortar joints..

2.1.1.2. Roof

The warehouse is a gabled roof with the ridge running in the north/south direction. The roof is a structural standing seam metal roof installed on purlins and having batt insulation installed on the underside of the roof. Gutters are located on the east and west sides of the building with downspouts draining directly to grade and not connected to an underground storm system. The roof was not accessible at this time, but it is our understanding that the roof had previously been assessed and was found to be in poor condition and would need replacement. Based on review of arial images it appears that portions of the roof have been repaired in the past, as well as appears like there are several areas of discoloration and corrosion. The canopy over the dock on the north side of the building is of similar construction as the main building roof, and is in poor condition with holes in the roof caused by corrosion. Based on the age of the roof it is nearing the end of its life and should be replaced.

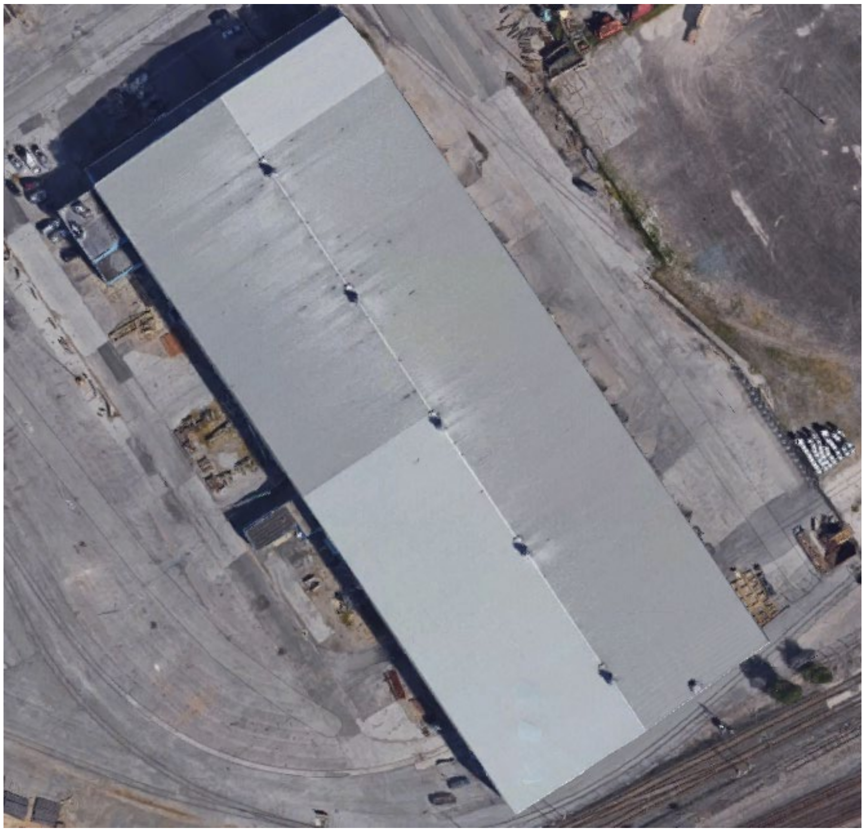


Photo 2.1.1.2.1 Arial image of the main warehouse roof. The roof is a structural standing seam metal roof. A portion of the roof in the northeast corner and the southwest side has been repaired previously. There are areas of staining and apparent corrosion occurring as well.

The roofs over the attached office, substation, and sprinkler rooms have built-up asphalt roofs and are likely original to the building. Review of the arial images shows differential wear and asphalt blisters and pooling. The coping around the office block was also observed to be warping and pulling away from the wall. Based on the age is at the end of its useful life and should be replaced.

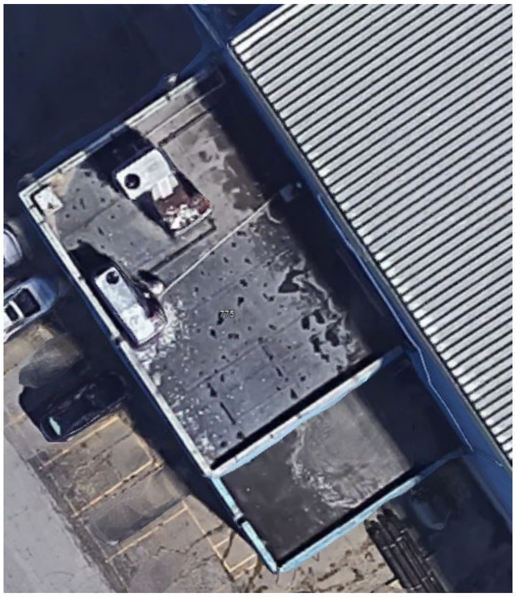


Photo 2.1.1.2.2 Arial image of the Office roof. Existing roof appears to be a built-up asphalt roof. Areas of asphalt blistering and pooling is observed.

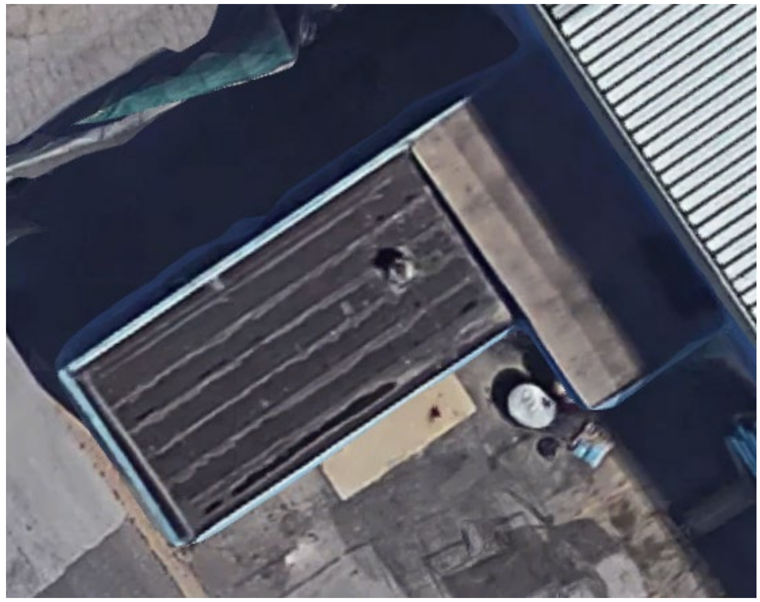


Photo 2.1.1.2.3 Arial image of the Substation roof. Existing roof appears to be a built-up modified bit roof. Areas of asphalt flowing from under the plies is observed.

Photo 2.1.1.2.4 Underside of canopy over the dock area on the north side of the building. The structural standing seam deck is in poor condition with holes caused by corrosion.

There is also a small canopy over one of the doors that was not part of the original construction and is constructed of steel plate. The paint on this canopy has failed and the canopy is corroding. As part of larger repairs this canopy should be removed, and possible replaced if required.

Photo 2.1.1.2.5 Canopy over existing door, is not original to the building construction and in poor condition. The paint on the canopy has failed and is beginning to corrode.

2.1.1.3. Doors

The doors at the warehouse is a mixtures of personnel doors and overhead coiling doors. The personnel doors are in poor condition. These doors have oil canning (waves) in the face sheets, corrosion of the doors and frames. The hardware on these doors is also not operating correctly. Additionally, door knobs are provide on the doors and not lever handles as required by ADA. There are also some doors where the exterior grade is below the finished floor creating a step at the doors. These steps create a tripping hazard, and are generally not allowed by the Code and will need to be corrected.

The overhead doors at the warehouse are overhead coiling doors with steel slates and are manually operated. The doors are generally in fair to good condition with some damage, but are operating. There are a couple of doors that are in poor condition and have failed. Many of these locations are no longer needed and are anticipated to be removed in the renovations.

Photo 2.1.1.3.1 Hollow metal door at the Office face sheet has oil canning and the paint has faded. There is also a small step at the door that presents a tripping hazard.

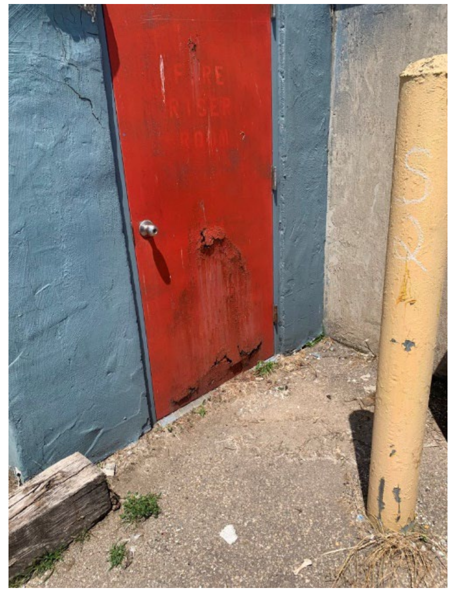


Photo 2.1.1.3.2 Hollow metal door has failed with sever corrosion and holes in the door.

Photo 2.1.1.3.3 Door hardware is not functioning properly with closers and locksets not working. Additionally doors are provided with knob handles and not levers as required by ADA.

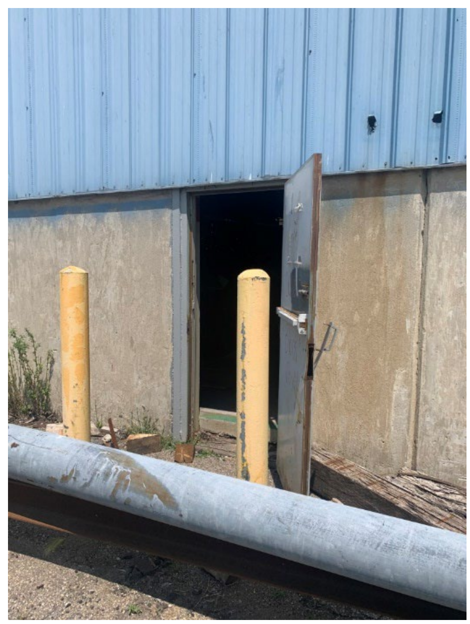


Photo 2.1.1.3.4 Existing door hardware does not operate correctly with closer and locksets not functioning.

Photo 2.1.1.3.5 Some of the existing overhead doors are in fair to good condition. There is some minor damage on the slates but the door is operating.

Photo 2.1.1.3.6 Overhead door is in poor condition and does not operate correctly. Door slats are damaged.

2.1.1.4. Windows

The warehouse is provided with a 5-foot high fiberglass translucent wall panel at the top of the east, west and south walls acting as a clerestory allowing for some diffused light to enter the warehouse. These panels are original to the building construction and like the wall panels are in fair condition at the end of their useful life. They provide minimal daylight into the space and will need to be replaced when the remainder of the wall panels are replaced. A window system that allows greater daylighting should be considered.

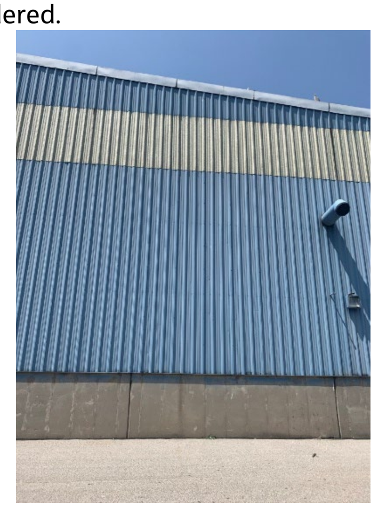


Photo 2.1.1.4.1 Translucent fiberglass clerestory panel on the south side has some staining and is in fair condition.

Photo 2.1.1.4.2 Translucent fiberglass clerestory panel at the top of the east wall of the warehouse. The panels are in fair condition. A portion of the panel on the left hand side is starting to pull away from the metal panel below.

There are also double hung windows located at the exterior of the Office building. These windows appear to have been replaced in the past and are in good condition. The sealant joints around the windows has dried out and is cracking and will need to be replaced.

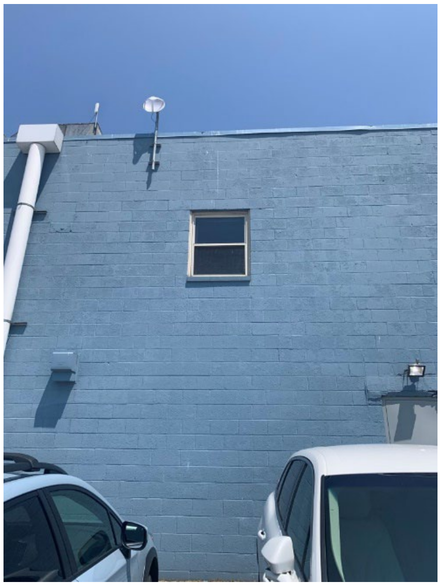


Photo 2.1.1.4.3 Office windows have been replaced and are in good condition. Sealant joints around the perimeter have reached their useful life and will need replaced.

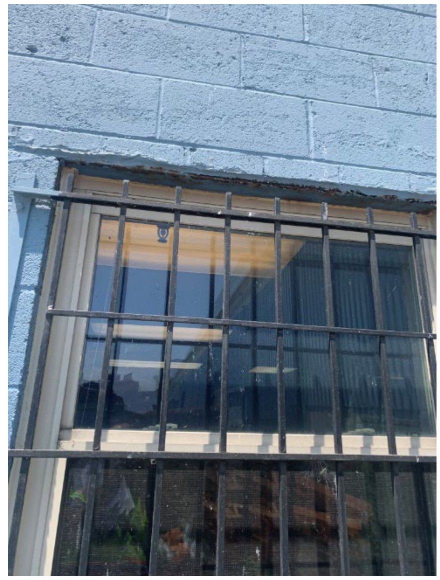


Photo 2.1.1.4.4 Office windows have been replaced and are in good condition. Sealant joints around the perimeter have reached their useful life and will need replaced.

2.1.2. Interior Construction

2.1.2.1. Wall and Ceilings

The interior walls of the warehouse consists of the exposed concrete abuse wall with a painted finish, and the scrim faced batt insulation on the backside of the metal wall panels. The finishes are generally soiled and dirty as expected based on age. The painted finish of the abuse wall has started to fail in some location with flaking pealing. The scrim face on the batt insulation has been damaged with holes and tears in many locations. The scrim facing acts as a vapor barrier and keeps moisture from condensing within the insulation and causing deterioration of the both the insulation and the backside of the wall panels. The insulation would be replaced with the exterior wall panel replacement.

Photo 2.1.2.1.1 Scrim face on the batt insulation is damaged. Scrim face acts as the vapor barrier to stop water from entering the insulation and condensing causing damage.

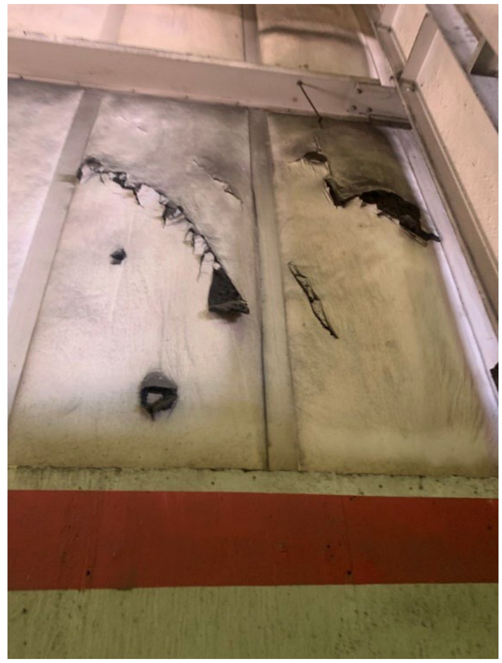


Photo 2.1.2.1.2 Scrim face on the batt insulation is damaged. Scrim face acts as the vapor barrier to stop water from entering the insulation and condensing causing damage.

Photo 2.1.2.1.3 Scrim face on the batt insulation is damaged. Scrim face acts as the vapor barrier to stop water from entering the insulation and condensing causing damage.

Photo 2.1.2.1.4 Paint and coating on the concrete abuse wall is failing and pealing.

The ceiling is similar to the wall construction with a scrim faced batt insulation exposed on the underside of the structural standing seam roof. There are locations where the insulation is damaged and falling way from the ceiling and would be replaced with the roof replacement.

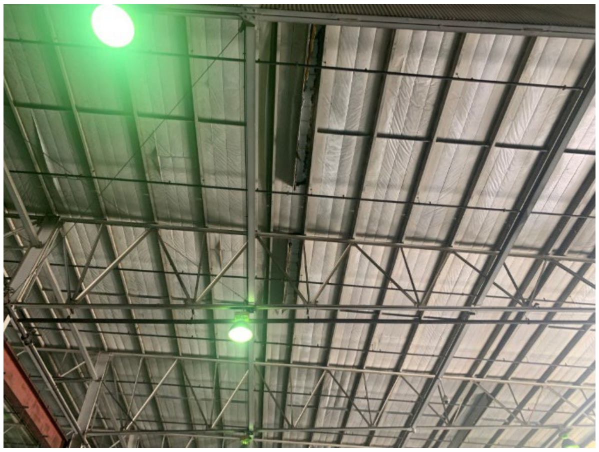


Photo 2.1.2.1.5 Scrim face on the batt insulation is damaged and falling away from the roof. Scrim face acts as the vapor barrier to stop water from entering the insulation and condensing causing damage.

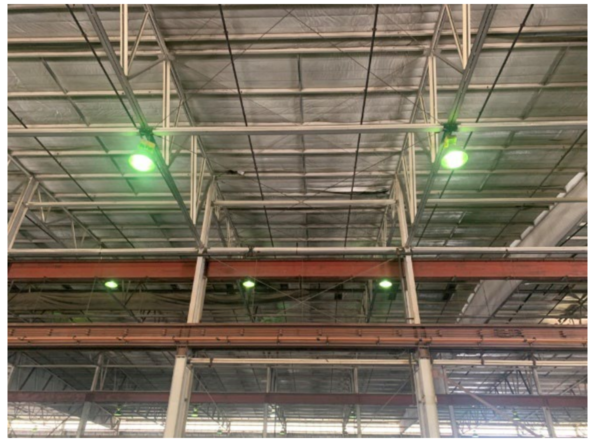


Photo 2.1.2.1.6 Scrim face on the batt insulation is damaged and falling away from the roof. Scrim face acts as the vapor barrier to stop water from entering the insulation and condensing causing damage

The structural steel columns, girts, roof trusses and purlins have a painted finish. Generally, these are in good condition with faded painted, but generally intact with only minor areas with some corrosion. It is recommended that all the steel be prepped and repainted.

2.1.2.2. Floors and Finishes

The floors in the warehouse are an asphalt floor designed for heavy loads. The flooring has settled considerable creating considerable slopes up to the door locations. The floor has also considerable amounts of cracking. The floor condition is described in greater detail in the structural section.

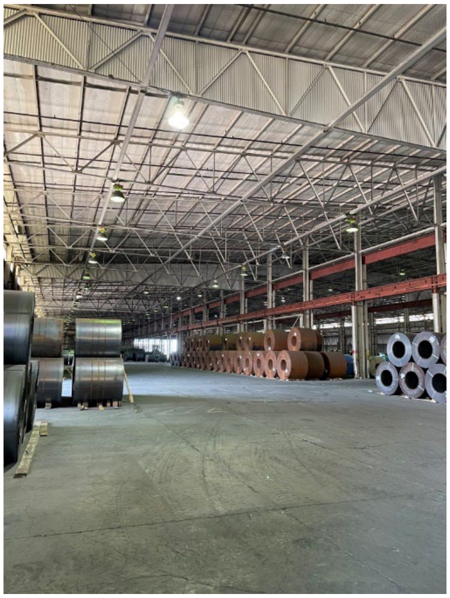


Photo 2.1.2.2.1 Interior asphalt floor in the warehouse have settled and have cracking throughout.

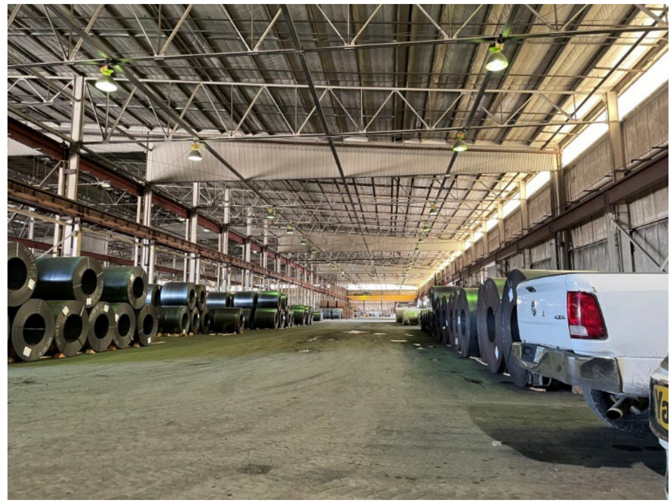


Photo 2.1.2.2.2 Interior asphalt floor in the warehouse have settled and have cracking throughout.

2.1.3. Architectural Recommendations

Based on the current conditions of the warehouse, and taking into consideration anticipated renovations to the building the following architectural recommendations are provided to extend the life of the building:

1. Warehouse Exterior Walls, Doors and Windows:
    a. At the concrete abuse walls repair cracks and spalled concrete area. Once complete apply an elastomeric coating over the entire wall.
    b. Remove and replace exterior metal wall panel with a new insulated metal wall panel. This will meet the Code required thermal requirements, while protecting the insulation from damage and providing a surface that is more easily cleanable.
    c. Remove existing translucent fiberglass panels and replace with a new clerestory window system. Replace with a fiberglass translucent window similar to Kalwall. Another consideration might be a clear glass aluminum window system to allow for increased daylight penetration and intensity.
    d. Remove all existing hollow metal doors and replace with new doors and door hardware.
    e. Remove and replace existing overhead coiling doors with new motor operated doors.
2. Warehouse Roof:
    a. Remove existing structural standing seam metal roof and batt insulation. Replace with new insulated metal roof.
    b. Remove and replace existing gutter and downspout.
    c. Remove and replace all existing eave trim.
3. Office Block Exterior Walls:
    a. Repair exterior masonry walls by tuckpointing and replacement of weathered CMU units.
    b. Repair/Replace existing lintels over all windows and doors.
    c. Remove and replace all doors, frames and hardware. At the exterior of doors provide new frost stoop level with the interior floor elevation.
4. Office Block Roof:
    a. Remove existing built-up roof system including roofing material and insulation down to the structural deck.

    b. Provide new modified bitumen roofing system including base and cap ply, cover board, 5-inches of rigid insulation, substrate board and vapor barrier.
    c. Provide new gutters and downspouts.
    d. Provide new roof edge trim and parapet copings.
5. Switchgear Exterior Walls:
    a. Repair exterior masonry walls by tuckpointing and replacement of weathered CMU units.
    b. Repair/Replace existing lintels over all windows and doors.
    c. Remove existing doors and provide new doors, frames and hardware.
6. Switchgear Roof:
    a. Remove existing built-up roof system including roofing material and insulation down to the structural deck.
    b. Provide new modified bitumen roofing system including base and cap ply, cover board, 5-inches of rigid insulation, substrate board and vapor barrier.
7. North most Sprinkler Room
    a. Demo existing walls and roof. Temporarily support existing sprinkler piping to remain.
    b. Rebuild in the room with CMU walls.
    c. Provide new door, frame and hardware.
    d. Provide new modified bitumen roofing system including base and cap ply, cover board, 5-inches of rigid insulation, substrate board and vapor barrier
8. Central and southern Sprinkler Room
    a. Repair exterior masonry walls by tuckpointing.
    b. Repair/Replace existing lintels over the doors.
    c. Remove and provide new doors, frames, and hardware.
    d. Provide new modified bitumen roofing system including base and cap ply, cover board, 5-inches of rigid insulation, substrate board and vapor barrier.

2.2 Structural Framing

Warehouse A was constructed with 25 structural bays running North-South with a column spacing of 24′-0″ on center and 3 structural bays running East-West with a 80′-0″ column spacing. Steel trusses span 80′-0″ supported on wide flange columns with a low point of +35′-0″ along the East and West elevations and a high point of +45′-0″ along the centerline for a 1/12 roof slope. The clear height underneath the trusses on the exterior bays is +30′-0″ and +40′-0″ in the center bay. Z-roof purlins spaced at 5′-6′ on center span between roof trusses to support the existing standing seam roof. The existing foundation system consists of 3-4 pile cap groups under steel columns, with a concrete grade beam spanning between pile caps along the perimeter.

Per the original construction drawings, 30 ton cranes were provided the full length of the building in each 80′ bay, with the center bay being the only one that is currently operational. Crane girders/rails span 24′-0″ to wide flange columns, matching the building framing in each bay.

The existing slab on grade is a 13″ concrete slab on compacted subgrade. Existing drawings appear to indicate that the original construction was a 13″ asphaltic concrete system, but has been replaced with the concrete slab at some point.

2.2.1 Main Building Framing

2.2.1.1 Building Support Structure

The existing steel trusses at 24′-0″ on center span 80′ in each bay are supported on wide flange columns that are in good condition with no visible damage. (Photos 2.2.1.1.1-2-3). The ¾″ diameter rod x-bracing that occurs in 3 bays on each column line running North-South are bent or loose at each location. X-bracing at each location to be tightened to provide adequate bracing for lateral loads. (Photo 2.2.1.1.4-5). The existing bottom chord strut located in the Southwest corner at the railroad track is damaged. (Photo 2.2.1.1.6). The existing girt framing supporting the metal siding on all elevations is in fair/good condition. (Photo 2.2.1.1.7-8). The existing wide flange columns are in good condition with only minor rusting at the base of the existing columns along the exterior elevations. (Photo 2.2.1.1.9). Several of the existing building columns and crane columns have concrete encasement installed in various configurations at the base to protect against impact damage from the crane. Concrete encasement is spalled due to impact loads. (Photo 2.2.1.1.10).

Photo 2.2.1.1.1 Center bay steel truss framing to wide flange steel columns at 24'-0" on center. Steel trusses and interior columns in good condition. Clean and paint all exposed steel.

Photo 2.2.1.1.2 East bay steel truss framing to wide flange steel columns. Minor corrosion at base of exterior columns, remainder in good condition. Clean and paint all exposed steel

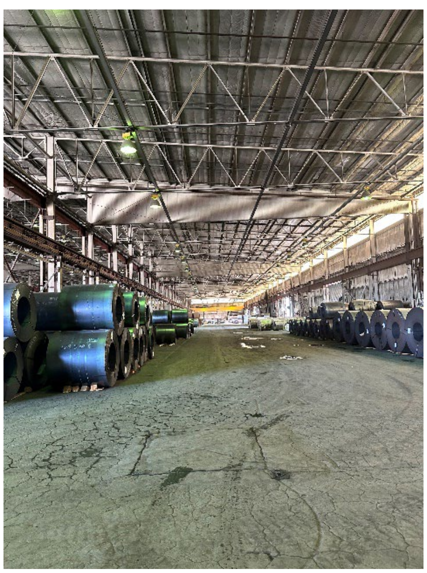


Photo 2.2.1.1.3 West bay steel truss framing to wide flange steel columns. Minor corrosion at base of exterior columns, remainder in good condition. Clean and paint all exposed steel.

Photo 2.2.1.1.4 X-Bracing located on West elevation. ¾" diameter rod bracing loose. Retention all rod x-bracing.

Photo 2.2.1.1.5 X-Bracing located on West elevation. ¾" diameter rod bracing loose. Retention all rod x-bracing.

Photo 2.2.1.1.6 Existing Strut spanning from bottom chord between trusses damaged at train bay. Replace strut.

Photo 2.2.1.1.7 Typical girt framing along East elevation in fair/good condition. Clean and paint

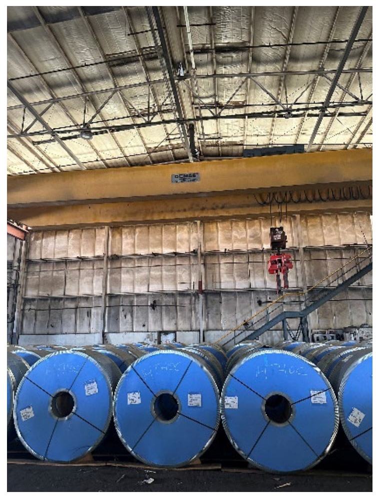


Photo 2.2.1.1.8 Typical girt framing along South elevation in fair/good condition. Clean and paint

Photo 2.2.1.1.9 Minor rusting at base of columns along exterior elevation – Clean per SSPC-3 minimum and paint

Photo 2.2.1.1.10 Existing concrete encasement at various crane/building columns damaged. Remove encasement and provide new concrete encasement at all column/crane columns to remain.

2.2.2.1 Crane Support Structure

The existing structure originally had 3–30-ton cranes, one in each bay running North-South. The existing crane in the East Bay has been removed along with the crane girder and rails. The existing crane columns and angle x-bracing remain in this bay. The existing crane in the West Bay is in place, but the crane rails have been removed. The crane girder, angle x-bracing and columns remain. The existing crane in the center bay is operational.

The existing crane columns in the center bay are damaged from impact load at 90% of the locations. (Photo 2.2.2.1-3). The crane columns in the center bay need to be replaced with new columns to properly align the existing crane girder. The crane columns in the East Bay were left in place and are damaged. The crane girder and rails have been removed. (Photo 2.2.2.4). The crane columns and x-bracing in the East Bay are recommended to be removed as they are obsolete. The angle x-bracing at all crane column locations is bent/damaged. (Photo 2.2.2.5-7). The existing crane in the West Bay is in place but is not operational. (Photo 2.2.2.8). The existing rail at this crane has been removed. The crane, crane columns and x-bracing in the West Bay are recommended to be removed as they are obsolete.

Photo 2.2.2.1.1 Existing crane column in center bay damaged by impact load.

Photo 2.2.2.1.2 Existing crane column in center bay damaged by impact load

Photo 2.2.2.1.3 Existing crane column in center bay damaged by impact load

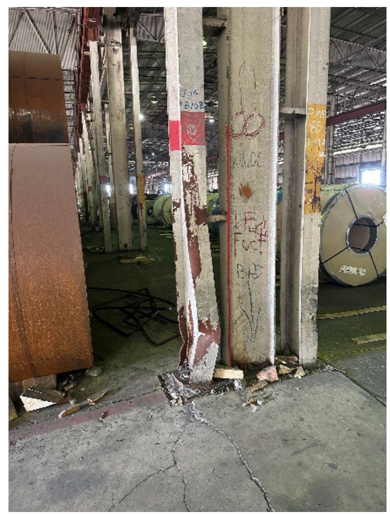


Photo 2.2.2.1.4 Existing crane column in East bay damaged by impact load

Photo 2.2.2.1.5 Existing angle x-bracing between crane columns bent/damaged.

Photo 2.2.2.1.6 Existing angle x-bracing between crane columns bent/damaged. Existing rod x-bracing between building columns loose.

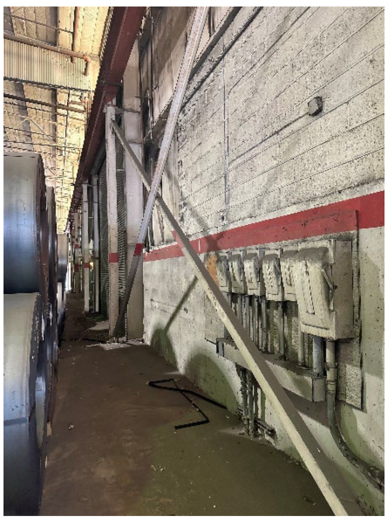


Photo 2.2.2.1.7 Minor rusting at base of columns along exterior elevation – Clean per SSPC-3 minimum and paint

Photo 2.2.2.1.8 Existing crane in West bay not operational. Crane rail removed, crane girders and columns remain

2.2.3.1 Slab-on-Grade

The existing 13″ concrete slab on grade slopes from a high point along the center of the structure running North-South to a low point along the exterior of the building on East and West elevations. The existing concrete slab is a floating slab supported on existing subgrade. The existing slab has excessive cracking throughout due to heavy floor loading with locations supporting steel coils settling up to 2’-0″ along the exterior of the structure (Photos 2.2.3.1-4)

Photo 2.2.3.1.1 Typical slab concrete cracking throughout entire surface of building

Photo 2.2.3.1.2 Slab failure with excessive settlement along East elevation

Photo 2.2.3.1.3 Slab failure with excessive settlement along West Elevation

Photo 2.2.3.1.4 Slab failure with excessive settlement, cracking and spalling along West elevation at overhead door.

▪ 2.2.4 Structural Recommendations

Based on the current conditions of the warehouse, and taking into consideration anticipated renovations to the building the following structural recommendations are provided to extend the life of the building:

1. Due to excessive settlements and heavy loading/impact requirements, it is recommended that a geotechnical investigation is provided to determine if the subgrade material can support the loading requirement without excessive settlements. The entire 13" concrete slab is recommended to be replaced with requirements for new support determined by geotechnical engineer.
2. Remove existing crane columns and angle x-bracing in the East Bay.
3. Remove existing crane columns, girders and x-bracing in the West Bay.
4. Replace all crane columns and x-bracing in the Center Bay, clean and re-use existing crane girders and rails.

5. Replace existing damaged strut at bottom chord framing in Southwest corner.
6. Re-tension all ¾" diameter rod x-bracing at main building column locations.
7. Provide new concrete encasement at base of building column/crane column in center bay to protect against impact damage from crane.

2.2. HVAC Systems

The HVAC system for the office area consists of two rooftop air handlers (both appear to be original to the building).
The old electrical room and restroom area are provided with an electric unit heater and exhaust fans. All equipment appears original to the building.

2.2.1. HVAC Recommendations

All HVAC equipment should be replaced and evaluated on the need for air condition and ventilation per its usage.

2.3. Electrical Systems

The electrical systems in Warehouse A, including utility feeds to the building, were observed and checked for their condition and their potential for reuse in an upcoming renovation.

2.3.1. Electrical Site Power

Electrical site distribution to Warehouse A originates from the east end of the site from CPP. While 12.47kV is available on the east end of the site near W 3rd Street, it's a 2.4kV primary line (see Photo 2.4.1.1 below) that is routed to Warehouse A and the adjoining two buildings. The primary line would need to be replaced with a new 12.47kV feed originating from W 3rd Street for the anticipated added loads in Warehouse A.
There is a series of flush-to-grade pull vaults (see Photo 2.4.1.2) between W 3rd Street. Markings on a CPP transformer serving one of the adjoining buildings confirms the 2.4kV primary feed (see Photo 2.4.1.3). An outdoor padmount utility transformer on the west side of Warehouse A currently serves the electrical panels in the building (see Photo 2.4.1.4).

Photo 2.4.1.1 Presence of 12.47kV primary power from CPP occurs on east end of Port Authority site, near W 3rd St

Photo 2.4.1.2 One of several CPP vault between W 3rd St and Warehouse A, used for 2.4kV primary feed to site

Photo 2.4.1.3 Padmount CPP transformer at building adjoining Warehouse A, clearly showing 2.4kV primary markings

Photo 2.4.1.4 Location of utility transformer currently providing 480V power to Warehouse A

2.3.2. Electrical Service and Distribution

While the building electrical wiring and feeders appears to date to the original 1975 construction, many of the electrical panels were replaced in 1992. On the west side of the warehouse, there are signs at floor level of an original switchboard that served the 480Y/277-volt panels using underground feeders (see Photos 2.4.2.1 and 2.4.2.2), but this has been removed. It now appears that these panels are fed directly from the outdoor utility transformer. A new main distribution panel is needed to serve downstream panels and to bring the facility up to code by adding a service disconnecting means and reliable grounding electrode system. For now, cutting power to the entire facility would require running between the individual panelboards through the whole facility, or cutting power at the primary side of the outdoor utility transformer.

Inside Warehouse A, there are six 100 to 225-amp panels (see Photos 2.4.2.3 and 2.4.2.4), all 480Y/277-volt, used primarily for serving overhead and outdoor lighting, but also serves other incidental 480Y/277-volt loads in the building, including the overhead cranes, roof fans, furnace blower fans, and step-down transformers for the handful of 208Y/120-volt power outlets and loads in the facility.

Several of the panels that serve outdoor lighting have electro-mechanical sub-meters (see Photos 2.4.2.5 and 2.4.2.6) that show energy/power usage of individual lighting circuits, but these no longer appear to be in service. Breakers are used for controlling indoor and outdoor lighting, in lieu of any wall switches or automatic lighting controls, such as by a lighting relay panel.

Many of the panels shows signs of neglect and dust intrusion (see Photo 2.4.2.7), and in some cases, physical damage from the floor slab heaving and shifting position, in one case crushing a pull box located directly under the panelboard for serving underground circuits (see Photo 2.4.2.8).

Many of power connections and starters for furnace blower fans (see Photo 2.4.2.9) and the overhead coiling doors on the exterior (see Photo 2.4.2.10) date to the original 1975 construction of the building, and are in poor to fair condition and should be replaced for safety and code compliance.

There are two overhead 30-ton cranes in the facility that use a busway system mounted on side of the support columns (see Photo 2.4.2.11). In at least one case the busway needs to be repaired and/or replaced in locations to assure a reliable power conductive connection between the moving brushes on the crane and the busway itself (see Photo 2.4.2.12).

Panels inside the office addition next to the Warehouse are a mix of panels from the mid-1970s and those installed and/or replaced in 1992 (see Photos 2.4.2.13 and 2.4.2.14).

Finally, there is overhead busway that is secured to the sides of the interior support columns. This busway appears to date to the original 1975 construction of the building and is in fair condition. The busway uses fused safety disconnects for serving connected loads. If it is reused, a thorough interior inspection of the busway for the condition of its busbars and connections is strongly recommended. Replacement should be considered so it is sized for anticipated connected loads, and can be assured of a 30 to 50 year lifespan following a major renovation.

Photo 2.4.2.1 Concrete pad on west side of Warehouse A shows where a main switchboard was demolished

Photo 2.4.2.2 Close-up of conduits through concrete pad for removed switchboard

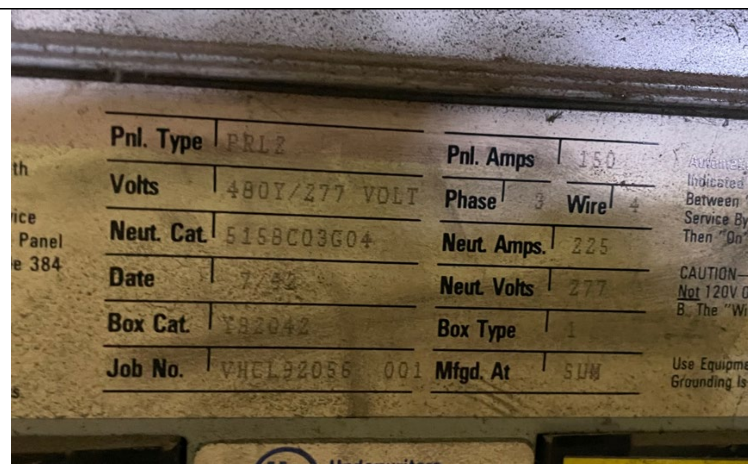


Photo 2.4.2.3 Panel PE on west side of Warehouse A, used for switching outdoor lighting.

Photo 2.4.2.4 Close-up of Panel PE nameplate shows this panel was installed in 1992

Photo 2.4.2.5 Panel on east side of Warehouse showing energy sub-meters

Photo 2.4.2.6 Panel on west side of Warehouse showing energy sub-meters

Photo 2.4.2.7 Close up of Panel PA, showing condition of circuit breakers

Photo 2.4.2.8 Side view of Panel PA shows where floor at east side of Warehouse A has heaved upwards, crushing wireway below the panelboard

Photo 2.4.2.9 Close-up of starter/disconnect for furnace of south end of Warehouse A

Photo 2.4.2.10 Overhead coiling door on east side of Warehouse, showing A-B starter

Photo 2.4.2.11 View of side of support beam on west side of Warehouse A, showing where crane busway has been removed

Photo 2.4.2.12 Close up showing how crane commutators connect to busway on side of support beam

Photo 2.4.2.13 Panelboards serving two story office on east side of Warehouse A appear to date to 1970s era construction

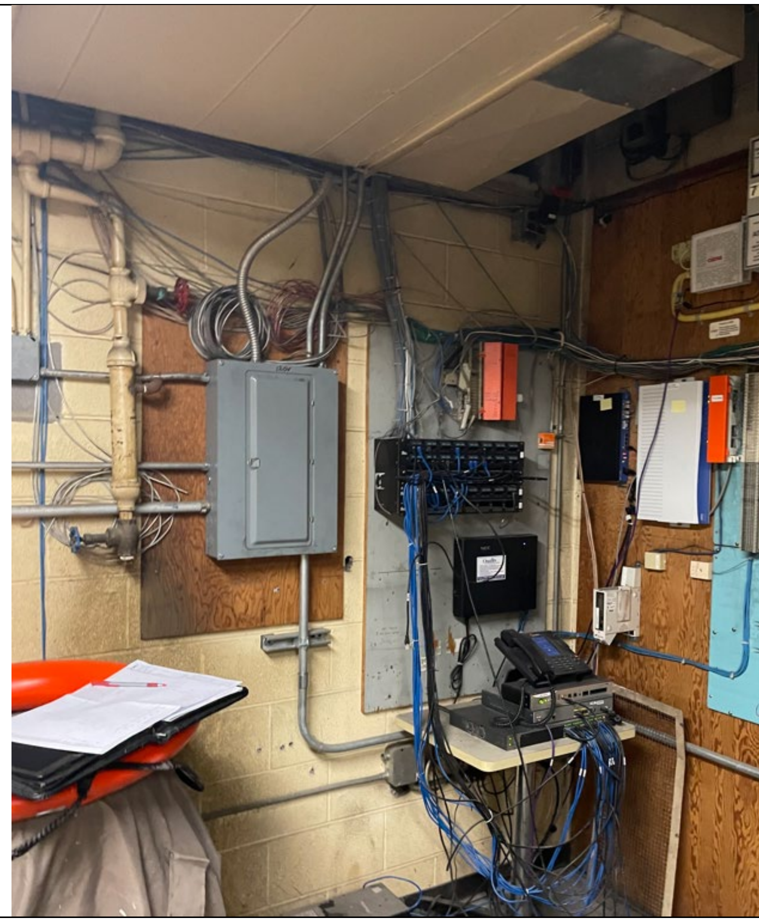


Photo 2.4.2.14 Communications utilities and IT racks are in first floor mechanical/storage room in two story office addition

2.3.3. Lighting

Exterior lighting on the west and east faces of Warehouse A were originally HID wall packs, which have been replaced by LED wall packs in the last ten years; these appear to be in good to excellent condition and other than cleaning, can be reused as is (see Photo 2.4.3.1). Warehouse A also serves several outdoor high mast pole lights south and west of the building, that appear to be HID lighting. In a remodel, these lights would need to be reconnected, though upgrade to LED lighting is recommended.

Interior lighting is largely based on HID high bay lighting (see Photos 2.4.3.2 and 2.4.3.3) that is mounted to an overhead wireway. Lighting is circuited to one of several distribution panelboards located on the exterior wall of the warehouse. This lighting is in fair condition. High bays are mostly open and not lensed, so when a lamp fails, there is a risk of falling debris in the space below.

Existing high bay locations can be used for providing LED high bays to provide even lighting with 'instant on' capability in the event of utility power interruptions. This would also allow the lighting to be replaced with lensed / gasketed LED lighting that would keep out dust and remove the hazard from HID lamp failure.

At most exit doors, there are combination exit signs and emergency wall packs (see Photo 2.4.3.4) that are in poor to fair condition, with many showing signs of damage or no longer illuminated. Since these appear to be over ten years in age, and most batteries have a five to seven year lifespan, replacing these one-for-one is recommended.

Photo 2.4.3.1 Close up of wast side of Warehouse A showing LED wall pack used for area illumination

Photo 2.4.3.2 View to the south on east half of Warehouse A, showing two rows of HID high bay lighting

Photo 2.4.3.3 Close up of high bay lighting showing mounting to overhead electrical wireway

Photo 2.4.3.2 Exit sign on east side of Warehouse A. Damage shown here is typical of most exit doors.

2.3.4. Fire Alarm

On the west side of Warehouse A, close to the location of the outdoor utility transformer and a previously removed switchboard (see Section 2.4.2 above), there is a Silent Knight Model 5207 fire alarm panel (see Photo 2.4.4.1) that is no longer in operation.

We did not see any fire alarm notification appliances (horn/strobes and strobes) in the Warehouse itself, nor were any manual pull stations noted at the exits (see Photo 2.4.4.3). Complete replacement of the fire alarm system is recommended for a building remodel.

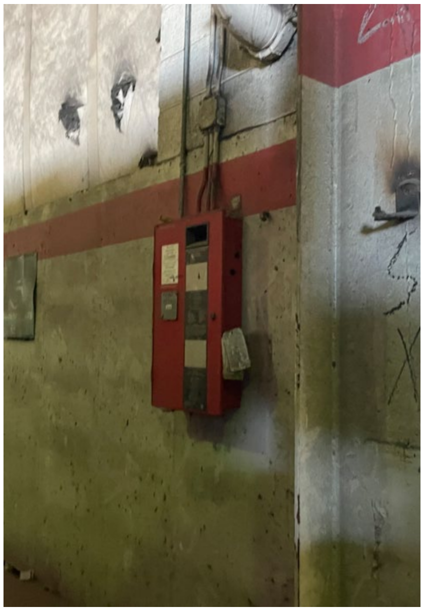


Photo 2.4.4.1 Non-functioning fire alarm control panel located at west side of Warehouse A

Photo 2.4.4.2 Absence of fire alarm horn/strobe and manual pull stations noted at exits at Warehouse A

2.3.5. Electrical Recommendations

Based on the condition of existing equipment, the following steps are recommended as part of the upcoming renovation with regard to building electrical systems:

1. Reuse building exterior LED wall packs and reconnect power needed.
2. Replace interior HID high bays with LED equivalents. For energy savings without compromising safety, such high bays can have integral high bay motion sensors and drop to a programmed lower light level when the space is unoccupied. Using motion sensors also removes the need for a lighting relay panel for lighting controls.
3. Replace exit signs one for one. For emergency lighting, it's recommended to use either a generator or mini-inverters so there is even overhead light in the event of a power outage.
4. Test power feeders to existing 480-volt panelboards to check the condition of their insulation, and replace as needed.
5. Replace 480-volt and 208-volt panelboards one-for-one, both to ensure circuit breakers will safely remove any downstream short circuits or overloads, but also to ensure they are rated for the available fault current, since this will change with a change in the electrical service.
6. Provide a new fire alarm system for the building, including ADA-compliant strobes and pull stations as required by code at designated exits.
7. Refurbish or replace the overhead bus track for the overhead cranes to ensure they will work reliably without any loose connections.
8. Add new electrical switchboard (480/277-volt) with integral surge protection, sub-metering as required, and a new grounding electrode system, both to bring the electrical service up to code, but also assure that the return ground path for short circuits is reliable so circuit breakers can clear line-to-ground faults.
9. Given the value of equipment to be placed in Warehouse A, and historic incidence of lightning strikes in the downtown area, add a lightning protection system to the building and two levels of surge protection (main electrical switchboard as recommended above, and at sub-distribution panels, to protect both variable frequency drives and power supplies of sensitive electronic equipment, including the drivers of LED lighting).

Section 3. Civil and Site

3.1. Civil/Site Condition Assessment

On July 18, 2023, a civil engineer from Osborn conducted a site conditions assessment. During the visit, they walked around Warehouse A and evaluated the condition of the pavement, surface drainage, above ground utilities, and surface markers. They also got a general idea of the site's topography.
Warehouse A is surrounded by asphalt pavement that is used for temporary storage of miscellaneous materials and access to overhead doors to the warehouse. In addition to the asphalt pavement there is an existing road (also asphalt surface) with concrete curb along west side. The condition of the pavement is poor. The surface is heavily cracked with grass peaking from the cracks. The existing road is also cracked with potholes, dips in pavement due to heavy traffic, numerous patches, and heavily cracked concrete curb. Along the north side of the Warehouse there an existing retaining wall (roughly 4 feet tall) with an access ramp used to access north side. The retaining wall is also in a poor shape as well as asphalt surface adjacent to the retaining wall.
Along east side of the warehouse the grade drops from south to north with large low area ponding water. Pavement along south side of the warehouse is in a relatively good condition as this area appears not to be used.
The warehouse has numerous small diameter downspouts discharging directly to the pavement surface that drains to roadway catch basins (along west side) and catch basins along east side. The existing northwest annex area has four large diameter downspouts that also discharge to pavement surface.
FDC is located along NW corner and hydrants are present at regular intervals around the building and are feeding into the building.
There is an existing bathroom in the NW annex building that apparently tie-ins to the sanitary sewer along north side.

Photo 3.1.1 Pavement along west side of the warehouse and roadway with concrete curb (photo looking south).

Photo 3.1.2 Pavement along west side of the warehouse with abandoned RR tracks (photo looking north).

Photo 3.1.3 Large diameter downspouts along NW annex building

Photo 3.1.4 Condition of pavement along west side

Photo 3.1.5 East side of warehouse with ponded water between building and railroad tracks

Photo 3.1.6 Pavement along east side; standing at southeast of the building looking north

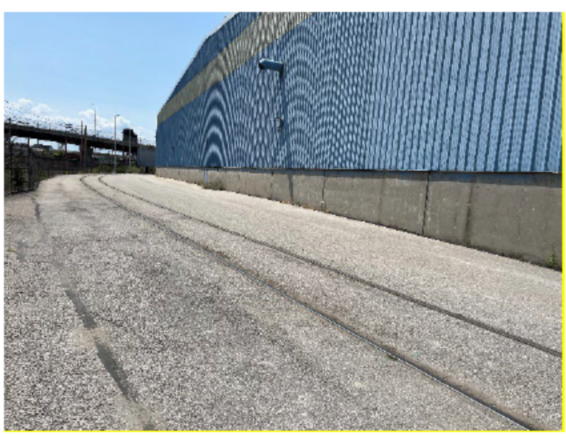


Photo 3.1.7 Pavement and railroad tracks along south side

Photo 3.1.8 Retaining wall, ramp and pavement along north side

3.1.1. Civil/Site Recommendations

Following recommendations were based on visual inspection, review of existing basemap, and stormwater masterplan:

1. Grading along east side to be adjusted to achieve proper drainage.
2. Pavement to be replaced along east and west sides.
3. Retaining wall along north side to be replaced as well as pavement.
4. Pavement along south side appears to be in ok conditions and can be left as is.
5. Tie-in downspouts to a storm sewer (new sewer). Follow stormwater masterplan when planning new sewer layout.
6. Testing of waterline to confirm available pressures (to be coordinated with fire protection needs).
7. Conform hydrant layout meets current Fire Department regulations.

No information on sanitary line. Confirm size is adequate for new bathroom facility and consider installing floor drains inside budling that will need to be incorporated in the new floor layout.

Appendix K
Federal and State Incentives

K. Federal and State Incentives

Table K-1. Federal Incentives

Funding Entity		Program	Program Amount	Program Goals	How it applies to the Port
Federal	EPA	Inflation Reduction Act (IRA) of 2022	$3 billion	The program addresses environmental challenges in regions with air quality concerns, with an appropriation of $3 billion, including $750 million reserved specifically for non-attainment areas available through Fiscal Year 2027. Funding eligibility encompasses a wide range of initiatives, including the procurement and installation of equipment or technology directly benefiting ports or facilitating port-related activities. This includes investments in cleaner technologies for cargo handling equipment, ships, and other port-related vehicles, as well as infrastructure for shore power and alternative fueling stations. The program also supports planning, permitting, and the development of climate action plans, ensuring comprehensive efforts to reduce emissions and enhance environmental performance.	Port is considered an eligible recipient of these funds to help them further their push to zero emissions. While these funds can be used for a variety of functions such as creating a climate action plan, a large portion of the funds are to be allocated for purchase of ZE port vehicles such as class 6 and 7 vehicles as well as specialized port equipment such as harbor craft and cargo handling equipment.
	EPA	Clean Heavy Duty Vehicles	$1 billion	The program sets aside $400 million specifically for non-attainment areas to address air quality concerns. Class 6 and 7 vehicles are eligible for participation, encouraging a broader range of vehicles to transition to cleaner technologies. The program offers a combination of direct grants and rebates, as well as subcontracting of grants and rebates to eligible contractors, to facilitate the deployment of clean heavy-duty vehicles. Funding under the program can cover various activities, including planning and technical assistance, incremental vehicle costs, fueling infrastructure development, and workforce development to support the transition to cleaner technologies. Funds will remain available through Fiscal Year 2031 to sustain and scale the initiative's impact over the long term.	Port is considered an eligible recipient of these funds, particularly for Yard Tractors

Funding Entity	Program	Program Amount	Program Goals	How it applies to the Port
FHWA	Reduction of Truck Emissions at Port Facilities Grant Program	$160 million	FHWA is seeking to address projects which address safety, climate change and sustainability, equity and justice40, as well as topics related to workforce development, job quality, and wealth creation. The objective of this program is to fund coordinated efforts to reduce emissions at ports, including electrification of operations. Funding under the program may cover the testing, evaluation, and deployment of technologies which reduce emissions from efficiency improvements and/or integration of clean technologies. The solicitation for the first round of funding of $160 million closed in July 2023. Future solicitations are expected each year for the next 3 fiscal years (2024-2026) for $80 million each.	Port is an eligible candidate for this program based on its focus of purchasing zero emission port vehicles that are being used to transfer freight shipments between two or more modes of transportation.
MARAD	Port Infrastructure Development Grants (PIDP)	$2.5 billion	Additionally, the Port Infrastructure Development Grants (PIDP) can be used for funding port electrification projects and charging infrastructure. The Bipartisan Infrastructure Law allocated $2.5 billion for the PDIP Port Infrastructure Development Program over 5 years starting in 2022.While other Federal incentive programs exist to support fleet electrification at ports, the PIDP and IRA funding are the largest programs to date and a great option to help Port continued efforts in fleet electrification.	Port is an eligible applicant for this program and has previously won funding for electrification projects at the port.
U.S. Department of Transportation (DOT)	Carbon Reduction Program	Part of IRA ($3 Billion)	The funds will be used for vehicle-to-infrastructure communications equipment, truck stop electrification, including charging or fueling infrastructure, the purchase or lease of ZEVs and port electrification.	Port with its advancement of port electrification is a qualified candidate for this program.
U.S. Department of Transportation (DOT)	U.S. Marine Highway Program	~$12 million	The program was created for investments in our marine highways to help strengthen our supply chains and reduce emissions. These grants have supported the development and improvements of ports infrastructure. Over $12 million was awarded in 2023 across the U.S.S and is expected to have more funding opportunities for zero emission projects in the upcoming years.	Further exploration is required to determine eligibility

Funding Entity	Program	Program Amount	Program Goals	How it applies to the Port
EPA	Inflation Reduction Act (IRA) of 2022 Section 45V hydrogen Production Tax Credit		The Section 45V tax credit offers up to $3 per kilogram for clean hydrogen production, representing a significant incentive to promote the development and adoption of hydrogen as a clean energy source in the United States. The credit is effective for hydrogen produced after December 31, 2022, for facilities that commenced construction before January 1, 2033.	This credit is expected to have a significant role in driving down the cost of hydrogen fuel for end users to accelerate adoption of hydrogen end uses.
EPA	Inflation Reduction Act (IRA) of 2022 Section 45W Commercial Clean Vehicle Credit		Effective after December 31, 2022, the Section 45W tax credit is designed to encourage the use of zero-emission vehicles (ZEVs) and other clean technologies in the commercial transportation sector. The credit offers financial support either by covering the incremental cost of the ZEV or providing 30% percent of the total price, whichever is lower. For vehicles with a Gross Vehicle Weight Rating (GVWR) below 14,000 pounds, the maximum credit available is $7,500, while for other commercial vehicles, the maximum credit can go up to $40,000.	The program allows taxpaying entities to lease the qualifying vehicles to tax-exempt entities, promoting the deployment of clean vehicles in a broader range of applications, including non-profit and government-related activities.
MARAD	Maritime Environmental and Technical Assistance	N/A	The program supports research and development of emerging technologies, practices and processes in maritime industrial environmental sustainability. They develop partnerships with other agencies in collaborative cost-sharing efforts for decarbonization and emission reduction technology.	Thus far they have developed several technologies that can be applied directly to vessels or placed at ports to reduce air emissions, among others.
EPA	The FAST Electricity Act of 2022	N/A- Tax Credit	Expands the existing loan program and create a new federal tax incentive to accelerate the manufacturing and adoption of all types of electrified transportation. expands the tax credit for plug-in electric drive motor vehicles to include a 30% percent credit for additional electric transportation options capable of moving passengers, cargo, or property and powered by an integrated, on-board electric propulsion system. The FAST Electricity Act's Qualified Electric Transportation Option" applies to vessels and vehicles that can move passengers or cargo and are	Will help fund the transition to battery electric for a variety of vehicles: specifically the work barges, Jetsam and Flotsam.

Funding Entity		Program	Program Amount	Program Goals	How it applies to the Port
				powered by an integrated onboard electric-propulsion system with a battery capacity of at least 8 kWh. It also allows a credit for recharging and hydrogen refueling property and provides loan guarantees for transportation electrification domestic manufacturing facilities. The bill's framework calls for a federal tax credit of 30% percent (valid from January 1, 2022, to December 31, 2028, then decreasing by 5% percent each year and going to 0% percent after 2032) for emerging electric-transportation options beyond passenger cars, including planes, boats, and recharging and hydrogen-refueling stations. It also seeks to provide federal loan guarantees to support capital investments in associated domestic manufacturing capacities.	

Table K-2. State Incentives

Funding Entity		Program	Program Amount	Program Goals	How it applies to the Port
State (Ohio)	Ohio Department of Transportation (ODOT)	Maritime Assistance Program (MAP)	$10 million	The program provides funding to eligible Ohio port authorities for planning, design, acquisition and infrastructure projects that increase the efficiency or capacity of maritime cargo terminal operations.	The program supports funding for the Port to acquire cargo handling equipment, all types of ship loading/unloading equipment, as well as construction and repair of warehouses and other structures.
	Ohio EPA	Diesel Mitigation Trust Fund (DMTF)	$4 million	The program is specifically targeting in replacing on- and off-road vehicles and equipment and will use $4 million for projects to replace aging diesel cargo handling equipment, forklifts, freight-switcher locomotives, and more.	Given the many specialized off-road vehicles operated by the Port, DMTF is a great program to help offset the higher costs of EVs with the program offering incentives.
	Ohio EPA	Alternative Fuel Vehicle (AFV)	N/A	The AFV exemption program is designed to exempt any vehicle powered exclusively by electricity, propane or natural gas, from state motor vehicle emissions inspections after a one-time verification inspection.	This allows Port to continuously use the electrical vehicles for the duration of its life cycle.

Appendix L
Future Phase Cost Estimates

Electrification and Warehouse A Modernization Project

Date: September 26, 2023

Project name: FISCAL YEAR 2022 PORT INFRASTRUCTURE DEVELOPMENT PROGRAM FUTURE PHASES

Executive Summary

This is an AACE Class V cost estimate organized to follow the previous FY2022 budget cost structure. Direct labor, material and equipment cost items and subcontractor cost quotes form the majority of costs. The balance of costs use previous budget estimate items, or current market prices from analogous scope. This estimate provides costs for scope items anticipated to be performed in future phases.

Cost Element	Estimated Cost	Accuracy Range	Cost Range
Phase 2 Chargers	$3,526,717	-30% to +50%	$2.5 – $5.3M
Phase 3 Charger Canopy	$336,460	-30% to +50%	$0.2 - $0. 5M
Phase 4 Cold Ironing	$24,026,347	-30% to +50%	$16.8 - $36.0M
Phase 5 Refeed Buildings	$998,965	-30% to +50%	$0.7 – $1.5M
Phase 6 Solar Roof	$6,898,700	-30% to +50%	$4.9 - $10.5M
Totals	$35,787,189	-30% to +50%	$25.1 – $53.7M

Project Information

The project is the Port Infrastructure Development Program, situated in Cleveland, Ohio, on Lake Erie shore.

Design Documents

The previous FY2022 budget provided the scope of work, supplemented by revisions, conceptual plans for the new structure additions, maps, layout sketches and markups. The design development is the major driver in determining the accuracy range of the estimate, and the stage of design is conceptual, therefore an AACE Class V range of accuracy is the most appropriate Class for this estimate.

Methodology

This estimate utilizes the previous FY2022 budget costs for selected scope items where little design information was available, totaling less than 5% of the cost. The scope and design information was sufficient to allow approximately 40% of the cost to be composed of separate items with labor, material and equipment cost types, together with another 20% to be composed of subcontractor cost type. Lastly, vendor quotes and analogous market prices comprised the remaining 40% of costs.

Markups and Addons

The estimate assumes delivery by a general contractor with multiple subs (civil, roofing, solar and electrical, among others, as applicable). The General Contractor markups include:

- General Requirements – 6%
- Mobilization/Demobilization – 3%
- Overhead and Profit – 15%
- Bonds and Insurance – 2.17%
- Contingency – 12%
- Escalation – 2.75%

Disclaimer

This cost estimate is an opinion of construction cost. This and all cost opinions and forecasts are forward-looking, and while facts contribute to the development of the results, the degree and presence of uncertainties requires the end user to consider the range of accuracy and its corresponding confidence interval representing the uncertainty of the forecasts. Actual values may occur outside the accuracy range (a confidence interval of 80% describes the low and high accuracy range values of -30% and +50%) for reasons not knowable or anticipated at the time of preparation of this document.

Attachments

Cost Estimate Report, 8pp

Budget	Subcomponent	Scope	Description	Takeoff Quantity	Unit Price	Total
PHASE 2			**CHARGERS**			
	2A		**On Terminal Electrification & WHA Modernization Project Construction Project**			
		A04	**Electrical Dockside Equipment Charging Infrastructure Backbone**			
			12kV 200A CB	1 ea	81,216.71 /ea	81,217
			12kV 200A feeder PVC ug to chgr	700 lf	81.22 /lf	56,852
			1000VCD 300A EMT AG chgr to disp	8,000 lf	103.96 /lf	831,659
			4'wide raised wa kway	2,000 sf	81.22 /sf	162,433
			3' metal access stairs	3 ea	12,182.51 /ea	36,548
			DC charger dispenser mountings at walkway	32 ea	4,923.78 /ea	157,561
			Concrete foundation for wa kway pedestals	100 ea	406.08 /ea	40,608
			1440kW 12kV Charger Base Station	1 ea	2,093,459.17 /ea	2,093,459
			DC Charging Dispensers	32 ea	1,630.23 /ea	52,167
			Base Charging Station foundation	250 sf	56.85 /sf	14,213
			A04 Electrical Dockside Equipment Charging Infrastructure Backbone	**1 LS**	**3,526,717.06 /LS**	**3,526,717**
			2A On Terminal Electrification & WHA Modernization Project Construction Project	**1 LS**	**3,526,717.06 /LS**	**3,526,717**
			PHASE 2 CHARGERS	**1 LS**	**3,526,717.06 /LS**	**3,526,717**

Budget	Subcomponent	Scope	Description	Takeoff Quantity	Unit Price	Total
PHASE 3			**CHARGER CANOPY**			
	2A		**On Terminal Electrification & WHA Modernization Project Construction Project**			
		Q03	**Future ZE Hub - WHA Elec, Fuel, Maint (Chargers) CANOPY**			
			Welding, continuous fillet, single pass, 3/16" thick, 0.2#/L.F.	934 lf	19.01 /lf	17,753
			Canopy framing 6" and 8" members 150#@317LF	47,550 b	5.64 / b	268,020
			Metal roof decking, steel, open type B wide rib, galvanized, over 500 Sq, 1-1/2" D, 16 gauge	5,400 sf	9.39 /sf	50,688
			Q03 Future ZE Hub - WHA Elec, Fuel, Maint (Chargers) CANOPY	**1 LS**	**336,460.16 /LS**	**336,460**
			2A On Terminal Electrification & WHA Modernization Project Construction Project	**1 LS**	**336,460.16 /LS**	**336,460**
			PHASE 3 CHARGER CANOPY	**1 LS**	**336,460.16 /LS**	**336,460**

Budget	Subcomponent	Scope	Description	Takeoff Quantity	Unit Price	Total
PHASE 4			**COLD IRONING**			
	2A		**On Terminal Electrification & WHA Modernization Project Construction Project**			
		Q01	**Cold Iron Infrastructure, MHC Power/Disc, WHA Docks 22, 24W, 24E & 26E**			
			Dock 24 W	1 ls	8,516,764.86 /ls	8,516,765
			Dock 24 E	1 ls	7,722,243.78 /ls	7,722,244
			Dock 26 W	1 ls	7,787,338.35 /ls	7,787,338
			Q01 Cold Iron Infrastructure, MHC Power/Disc, WHA Docks 22, 24W, 24E & 26E	**1 LS**	**24,026,346.99 /LS**	**24,026,347**
			2A On Terminal Electrification & WHA Modernization Project Construction Project	**1 LS**	**24,026,346.99 /LS**	**24,026,347**
			PHASE 4 COLD IRONING	**1 LS**	**24,026,346.99 /LS**	**24,026,347**

Budget	Subcomponent	Scope	Description	Takeoff Quantity	Unit Price	Total
PHASE 5			**REFEED BUILDINGS**			
	2A		**On Terminal Electrification & WHA Modernization Project Construction Project**			
		Q07	**Refeed Buildings from Warehouse A**			
			500kVA xfmr & tie in exist secondary	2 ea	81,216.70 /ea	162,433
			150kVA xfmr & tie in exist secondary	1 ea	64,973.35 /ea	64,973
			112kVA xfmr & tie in exist secondary	2 ea	56,851.70 /ea	113,703
			12kV PVC ug circuit (underground ductbank)	8,100 lf	81.22 /lf	657,855
			Q07 Refeed Buildings from Warehouse A	**1 LS**	**998,965.40 /LS**	**998,965**
			2A On Terminal Electrification & WHA Modernization Project Construction Project	**1 LS**	**998,965.40 /LS**	**998,965**
			PHASE 5 REFEED BUILDINGS	**1 LS**	**998,965.40 /LS**	**998,965**

Budget	Subcomponent	Scope	Description	Takeoff Quantity	Unit Price	Total
PHASE 6			**SOLAR ROOF INCL. ROOF MODIFICATIONS**			
	2A		**On Terminal Electrification & WHA Modernization Project Construction Project**			
		Q05	**WHA Solar Panel and Inverter**			
			WHA Solar Panel and Inverter 2.15MWdc	2,150,000 Wdc	2.84 /Wdc	6,111,557
			Roof Structural Modifications 24 truss x 56 ea =	1,344 ea	585.67 /ea	787,143
			Q05 WHA Solar Panel and Inverter	**1 LS**	**6,898,699.74 /LS**	**6,898,700**
			2A On Terminal Electrification & WHA Modernization Project Construction Project	**1 LS**	**6,898,699.74 /LS**	**6,898,700**
			PHASE 6 SOLAR ROOF INCL. ROOF MODIFICATIONS	**1 LS**	**6,898,699.74 /LS**	**6,898,700**

Appendix M
Onshore Wind Power Analysis

M. Onshore Wind Power Analysis

M.1 Wind Generation

A similar study was conducted to determine the feasibility of onsite wind energy generation. The wind study was conducted using the Renewables Ninja energy modeling database, which has been cited in academic papers and scientific research across the globe. In addition to the Renewables Ninja database, the study also used data from a wind turbine at the Great Lakes Science Center (GLSC), located a short distance away from the project site, on the Cleveland waterfront.

The provided GLSC data only included 4 full months of wind turbine data, and had a capacity factor of less than 5 percent, which is drastically lower than the expected capacity factor for a wind turbine in this location. For this reason, the renewables ninja models were used to supplement the study. Three turbines from the renewables ninja database were selected that matched the desired system specifications of a turbine with a hub height between 30 and 40 meters and a nameplate capacity near 250 kW. The three turbines used in the models were the Vestas V27 225-kW turbine, the Nordex N29 250-kW, and the Wind Master WM28 300-kW turbine. The GLSC also uses the Vestas V27 225-kW wind turbine. The results of the study can be seen in Table M-1, showing that at the project site a 250-kW wind turbine would produce close to 450,000 kWh, annually, depending on the selected turbine model. For a two-turbine system, the estimated annual energy output would be roughly 900,000 kWh. The estimated monthly energy output of the different wind turbine models is displayed in Table M-2.

Table M-1. Wind Turbine Model Performance

Turbine Model	Vestas V27	Nordex N29	Wind Master WM28	Vestas V27 (GLSC)
Turbine Nameplate Capacity (kWdc)	225	250	300	225
Hub Height (m)	30	36	33	31
Capacity Factor (%)	21.2	21.5	16.5	4.4
Estimated Average Monthly Energy Output (kWh)	34,800	39,200	36,200	7,200
Estimated Turbine Annual Energy (kWh)	417,700	471,000	434,900	-
Two-Turbine Annual Energy Output (kWh)	835,400	942,000	869,800	-

% = percent
kWdc = kilowatt(s) direct current
m = meter(s)

Table M-2. Estimated Monthly Wind Turbine Energy Output

	Monthly Energy Output (kWh)			
Turbine Model	Vestas V27	Nordex N29	Wind Master WM28	Vestas V27 (GLSC)
January	62,276	66,074	69,663	11,090
February	48,734	52,625	55,138	4,295
March	44,255	48,814	47,609	-
April	37,750	42,773	39,393	-
May	26,396	31,284	26,223	-

Monthly Energy Output (kWh)				
June	21,680	26,365	20,397	-
July	12,898	16,630	10,690	-
August	15,177	19,095	12,958	-
September	19,740	24,199	17,763	-
October	38,554	43,463	40,148	-
November	40,381	45,070	42,219	6,530
December	49,881	54,676	52,731	7,129

In addition to the average daily and monthly energy production data above, Jacobs also quantified the split of wind produced energy during on- and off-shift times of day, using the Windmaster WM28 option as the preferred example (Figure M-1).

Figure M-1. Distribution of wind generation over a 24 hour period

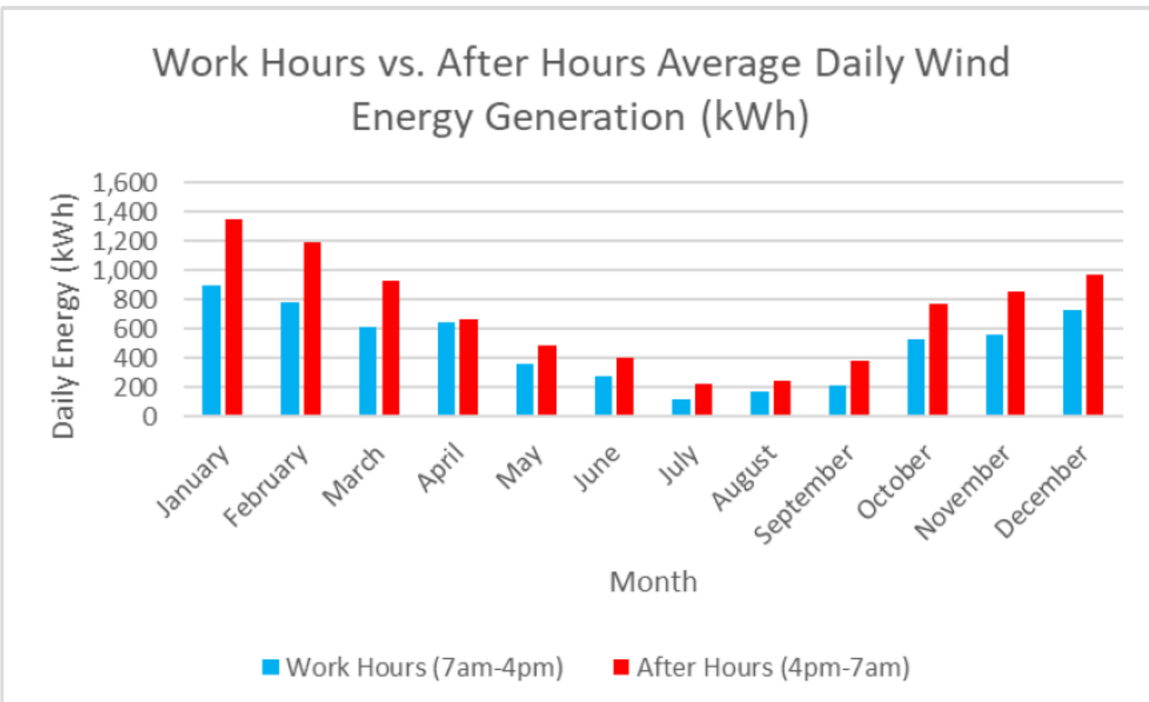


Figure M-2. Great Lakes Science Center Vesztas V27 Wind Turbine

Current Ohio rules on turbine placement relative to parcel can be challenging for the development of wind turbines. Particularly for the Port, which has multiple parcels with ownership split between the Port and the City, as illustrated on Figure M-1 and Figure M-2. "On June 28, 2021, the Ohio General Assembly passed Senate Bill (S.B.) 52, which places new requirements on renewable energy development in Ohio and changes to the Ohio Power Siting Board (OPSB) process" (Bricker 2021). The bill updated setback rules for economically significant wind farms stated as follows: "The minimum setback for shall be equal to a horizontal distance, from the turbine's base to the property line of the wind farm property, equal to one and one-tenth times the total height of the turbine structure as measured from its base to the tip of its highest blade and be at least one thousand one hundred twenty-five feet in horizontal distance from the tip of the turbine's nearest blade at ninety degrees to property line of the nearest adjacent property at the time of the certification application."

Importantly it is worth noting that this ruling applies to "'Economically significant wind farm[s]' – which are, with certain exceptions, wind turbines and associated facilities with a single interconnection to the electrical grid and designed for, or capable of, operation at an aggregate of five or more megawatts but less than 50 megawatts" (Bricker 2021). In the context of the capacity of the recommended two WM28 turbines are less than 5 MW and would not fall under this setback restriction per the policy.

M.2 References

Brickner. 2021. Ohio General Assembly passes S.B. 52: Changes to wind and solar siting requirements. https://www.bricker.com/industries-practices/energy/insights-resources/publications/ohio-general-assembly-passes-sb-52-changes-to-wind-and-solar-siting-requirements.

Appendix N
Glint and Glare Study for Warehouse A Solar PV Array

Subject	**Port of Cleveland Solar Glare Analysis Technical Memorandum**
Project Name	Port of Cleveland Solar Glare Analysis
From	Jacobs
Date	October 11, 2023

1. Project Overview

Jacobs has prepared this memorandum as a due diligence investigation for potential glint and glare impacts from the Port of Cleveland Solar project in the project area and its vicinity. The project site is located on one building located at the Cleveland Harbor, near Pier 20. The project includes approximately 2.15MW Solar PV arrays flush mounted on the existing building roof with a 4.5 degree slope.

Reflectivity refers to light that is reflected off of flat surfaces. The main impact of reflectivity is glare which can cause a brief loss of vision (or flash blindness). The amount of light reflected off a solar panel surface depends on the amount of sunlight hitting the surface as well as the surface reflectivity. The amount of sunlight interacting with the solar panel will vary based on geographic location, time of year, cloud cover, and solar panel orientation.

The purpose of this technical memorandum is to identify potential for glint and glare and to provide a summary and analysis of potential impacts.

2. Glint and Glare Methodology

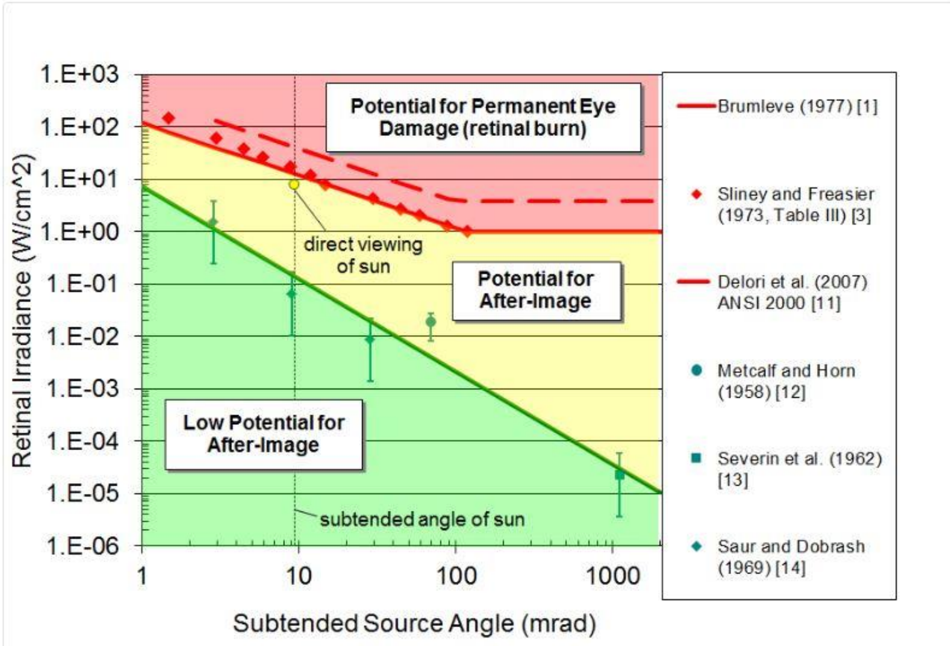
Jacobs conducted a glint and glare analysis and utilized ForgeSolar's GlareGauge software to assess user-input PV arrays for potential glare.

ForgeSolar's GlareGauge tool evaluates the occurrence of glare on a minute-by-minute basis. If glare is predicted, each minute of glare as a function of retinal irradiance and subtended angle is plotted on a hazard plot. The ocular impact of solar glare is quantified into three categories:

- Green (low potential for after-image),
- Yellow (potential for temporary after-image),
- Or red (potential for retinal damage).

Figure 1 depicts the glare hazard plot. The software can simulate obstacles and blocking geometries that may mitigate PV glare. For example, obstructions can represent tree cover, buildings, and geographic elements. Two buildings were included as obstructions in this analysis.

Figure 1. Glare Hazard Plot

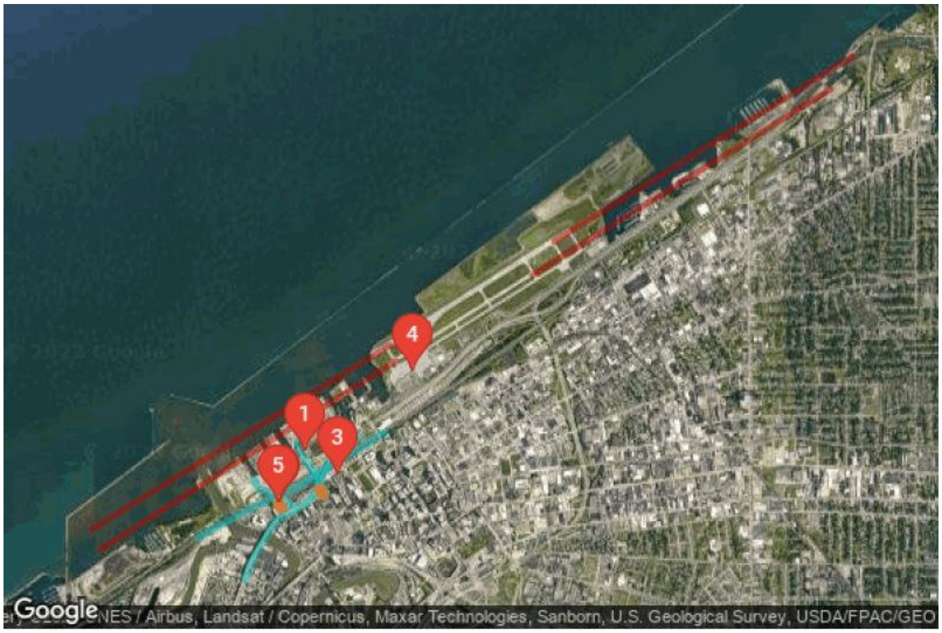


Source: ForgeSolar User Manual (Ho, 2011)

The assessment evaluated the following locations, depicted on Figure 2:

- Four Flight paths at the Cleveland Burke Lakefront Airport
- The Cleveland Burke Lakefront Airport Air Traffic Control Tower (ATCT)
- Three roads in the vicinity of the project (including State Route 2, W 3rd Street and W 9th Street)
- The Railroad Tracks south of the project area
- Four Observer Points (Two observers on different floors of the Ernest & Young Office Highrise, Cuyahoga County Courthouse Tower, and Cleveland Browns Stadium Overlook)

Figure 2. Observer Locations



Source: ForgeSolar

3. Glint and Glare Results

Table 1 summarizes results. The complete ForgeSolar analysis, including glare location and intensity, is attached in Appendix 1.

According to the ForgeSolar analysis, the ATCT is not expected to receive any glare. Flight paths to Runways 6L and 6R are expected to receive "green" and “yellow” glare with potential to cause temporary after-image. The glare would occur mainly during the mornings in the Spring and Fall. In addition, Runway 24L is expected to receive a very limited amount of “green” glare in the evenings in December.

The Federal Aviation Administration (FAA) policy *Review of Solar Energy System Projects on Federally-Obligated Airports*, published in May 2021, establishes FAA policy for proposals by sponsors of federally-obligated airports to construct solar energy systems on airport property. This policy states that FAA will rely on the submittal of Form 7460-1 in which the sponsor confirms that it has analyzed the potential for glint and glare and determined there is no potential for ocular impact to the airport's ATCT cab. In addition, the policy also states that in most cases, the glint and glare from solar energy systems to pilots on final approach is similar to glint and glare pilots routinely experience from water bodies, glass-façade buildings, parking lots, and similar features. Because of the location in close proximity to the lake it is anticipated that the glare received from the solar panels on the flight paths would be similar from the glare received from the lake.

In addition, ForgeSolar also indicates “yellow” glare with potential to cause temporary after-image on the railroad south of the proposed project. The glare would be located on a very short section of the railroad. Two of the observers (the Cuyahoga County Courthouse Tower, and Cleveland Browns Stadium Overlook) would receive a short amount of “green” glare. The glare received at the Cleveland Browns Stadium Overlook would be received mainly during the evenings in the winter. The glare at the Cuyahoga County Courthouse Tower would be received mainly during the evenings in the Spring and Fall. It is anticipated this amount of glare will be similar to the glare received from the lake and glass-façade buildings in the vicinity.

Table 1. Summary Results

Observer	Annual Green Glare (hours)	Annual Yellow Glare (hours)
Railroad	13.1	14.5
State Route 2	0.0	0.0
W 3rd St	0.0	0.0
W 9th St	0.0	0.0
Runway 24L Flight Path	1.4	0.0
Runway 24R Flight Path	0.0	0.0
Runway 6L Flight Path	117.1	13.4
Runway 6R Flight Path	146.3	61.5
Cleveland Browns Stadium Overlook	32.5	0.0
Ernest & Young Office Highrise	0.0	0.0
Cuyahoga County Courthouse Tower	39.9	0.0
Air Traffic Control Tower	0.0	0.0

4. Potential Alternatives and Mitigation

The glint and glare from solar energy systems is typically considered similar to glint and glare experienced from water bodies, glass-façade buildings, metal buildings, and similar features. However, glare from solar panels can still create both an annoyance to local residents and communities, and a safety hazard. A very short section of railroad is anticipated to receive yellow glare. Some potential options to mitigate predicted glare on the railroad include:

- Choosing a different tracking technology, angle, or height which can help reduce glare,
- Choosing a different tilt for the panels (suboptimal positioning), which can help reduce glare,
- Installing landscape screening to screen panels from view and help reduce glare,
- Installing warning signs to warn drivers and train conductors of potential solar glare hazards.

Further detailed evaluation and modeling is recommended to analyze whether different configurations, and/or including a short section of fence or landscape screening, would reduce the glare on the railroad. In addition, consultation with stakeholders that may be impacted by the project is recommended to share results.

5. References

Ho, C. K., Ghanbari, C. M., and Diver, R. B., 2011, "*Methodology to Assess Potential Glint and Glare Hazards From Concentrating Solar Power Plants: Analytical Models and Experimental Validation*", ASME J. Sol. Energy Eng., 133.

Attachment 1: ForgeSolar Glare Analysis

FORGESOLAR GLARE ANALYSIS

Project: **Port of Cleveland**
Site configuration: **Site 1**

Client: Port of Cleveland

Created 22 Aug, 2023
Updated 22 Aug, 2023
Time-step 1 minute
Timezone offset UTC-5
Minimum sun altitude 0.0 deg
DNI peaks at 1,000.0 W/m^2
Category 500 kW to 1 MW
(1,000 kW / 8 acre limit)
Site ID 98249.17157

Ocular transmission coefficient 0.5
Pupil diameter 0.002 m
Eye focal length 0.017 m
Sun subtended angle 9.3 mrad
PV analysis methodology V2

Summary of Results Glare with potential for temporary after-image predicted

PV Array	Tilt	Orient	Annual Green Glare		Annual Yellow Glare		Energy
	°	°	min	hr	min	hr	kWh
PV array 1	4.5	170.0	21,010	350.2	5,364	89.4	-

Total glare received by each receptor; may include duplicate times of glare from multiple reflective surfaces.

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Railroad	785	13.1	869	14.5
State Route 2	0	0.0	0	0.0
W 3rd ST	0	0.0	0	0.0
W 9th ST	0	0.0	0	0.0
RWY 24L	81	1.4	0	0.0
RWY 24R	0	0.0	0	0.0
RWY 6L	7,027	117.1	807	13.4
RWY 6R	8,778	146.3	3,688	61.5
OP 1	1,947	32.5	0	0.0
OP 2	0	0.0	0	0.0
OP 3	2,392	39.9	0	0.0
4-ATCT	0	0.0	0	0.0
OP 5	0	0.0	0	0.0

Component Data

PV Arrays

Name: PV array 1
Axis tracking: Fixed (no rotation)
Tilt: 4.5°
Orientation: 170.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
1	41.503881	-81.704842	578.28	45.00	623.28
2	41.504242	-81.704134	576.42	45.00	621.42
3	41.502860	-81.702879	580.19	45.00	625.19
4	41.502491	-81.703619	580.42	45.00	625.42

Route Receptors

Name: Railroad
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
1	41.507155	-81.692177	589.55	9.00	598.55
2	41.504953	-81.696833	584.43	9.00	593.43
3	41.503475	-81.700159	582.38	9.00	591.38
4	41.502928	-81.701189	581.91	9.00	590.91
5	41.502430	-81.702691	581.89	9.00	590.89
6	41.501578	-81.705137	580.27	9.00	589.27
7	41.500566	-81.707712	581.00	9.00	590.00
8	41.499380	-81.710699	582.39	9.00	591.39
9	41.498544	-81.712651	584.70	9.00	593.70

Name: State Route 2
Path type: Two-way
Observer view angle: 25.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
1	41.506877	-81.694939	591.16	3.50	594.66
2	41.505993	-81.696849	602.55	3.50	606.05
3	41.505640	-81.697407	597.52	3.50	601.02
4	41.505013	-81.698137	593.65	3.50	597.15
5	41.504290	-81.698544	582.87	3.50	586.37
6	41.502105	-81.699914	639.94	3.50	643.44
7	41.501542	-81.700451	640.73	3.50	644.23
8	41.501285	-81.700901	640.45	3.50	643.95
9	41.500835	-81.701953	638.54	3.50	642.04
10	41.500048	-81.703841	588.94	3.50	592.44
11	41.499823	-81.704184	583.34	3.50	586.84
12	41.499421	-81.704571	578.03	3.50	581.53
13	41.498424	-81.705322	568.45	3.50	571.95
14	41.496415	-81.706867	578.35	3.50	581.85
15	41.495114	-81.707510	595.61	3.50	599.11

Name: W 3rd ST
Path type: Two-way
Observer view angle: 25.0°

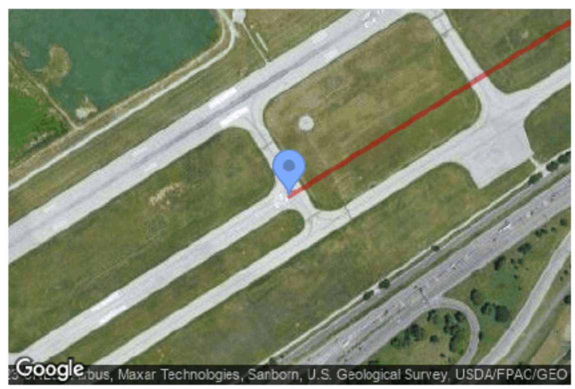
Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
1	41.506699	-81.701495	578.97	2.50	581.47
2	41.506201	-81.701709	581.60	2.50	584.10
3	41.505590	-81.701430	589.48	2.50	591.98
4	41.502135	-81.698448	643.15	2.50	645.65

Name: W 9th ST
Path type: Two-way
Observer view angle: 25.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
1	41.503303	-81.706543	577.96	3.50	581.46
2	41.502701	-81.706071	583.14	3.50	586.64
3	41.502548	-81.705931	585.31	3.50	588.81
4	41.501632	-81.702895	617.05	3.50	620.55
5	41.501206	-81.702488	627.44	3.50	630.94

Flight Path Receptors

Name: RWY 24L
Description:
Threshold height: 50 ft
Direction: 238.1°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°



Point	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
Threshold	41.520162	-81.675843	582.17	50.00	632.17
Two-mile	41.535444	-81.643024	572.66	612.93	1185.59

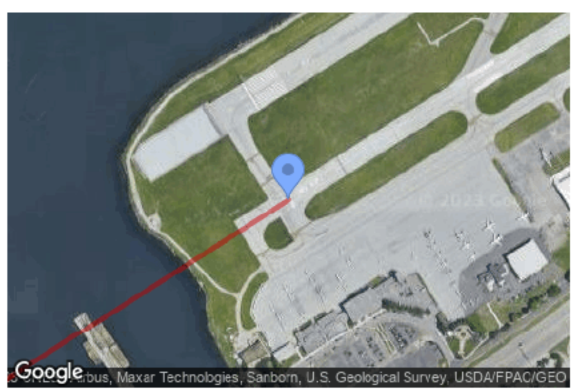
Name: RWY 24R
Description:
Threshold height: 42 ft
Direction: 238.2°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
Threshold	41.522897	-81.673502	581.42	42.00	623.42
Two-mile	41.538115	-81.640628	589.46	587.38	1176.84

Name: RWY 6L
Description:
Threshold height: 50 ft
Direction: 58.3°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
Threshold	41.514394	-81.691514	580.87	50.00	630.87
Two-mile	41.499184	-81.724390	568.45	615.85	1184.30

Name: RWY 6R
Description:
Threshold height: 50 ft
Direction: 57.4°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

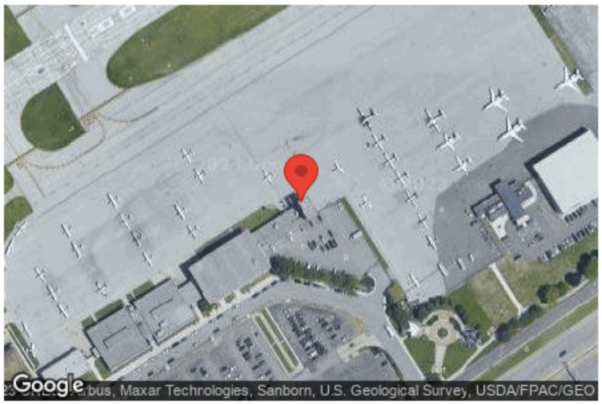


Point	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
Threshold	41.513098	-81.690855	580.66	50.00	630.66
Two-mile	41.497534	-81.723432	568.45	615.64	1184.09

Discrete Observation Point Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (ft)	Height (ft)
OP 1	1	41.505595	-81.700939	601.46	100.00
OP 2	2	41.501439	-81.703686	601.77	250.00
OP 3	3	41.503666	-81.697225	638.31	40.00
4-ATCT	4	41.512136	-81.689001	582.25	50.00
OP 5	5	41.501393	-81.703844	598.47	80.00

Map image of 4-ATCT



Obstruction Components

Name: Obstruction 1
Top height: 100.0 ft

Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)
1	41.502415	-81.698882	642.15
2	41.502155	-81.698652	643.32
3	41.501964	-81.699022	644.47
4	41.502518	-81.699517	636.38
5	41.502697	-81.699145	636.78
6	41.502416	-81.698884	642.15

Name: Obstruction 2
Top height: 330.0 ft

Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)
1	41.501364	-81.704070	592.78
2	41.500781	-81.703560	600.21
3	41.500972	-81.703184	610.79
4	41.501464	-81.703618	603.11
5	41.501343	-81.703891	597.04
6	41.501374	-81.703917	596.85
7	41.501324	-81.704029	594.18

Glare Analysis Results

Summary of Results Glare with potential for temporary after-image predicted

PV Array	Tilt	Orient	Annual Green Glare		Annual Yellow Glare		Energy
	°	°	min	hr	min	hr	kWh
PV array 1	4.5	170.0	21,010	350.2	5,364	89.4	-

Total glare received by each receptor; may include duplicate times of glare from multiple reflective surfaces.

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Railroad	785	13.1	869	14.5
State Route 2	0	0.0	0	0.0
W 3rd ST	0	0.0	0	0.0
W 9th ST	0	0.0	0	0.0
RWY 24L	81	1.4	0	0.0
RWY 24R	0	0.0	0	0.0
RWY 6L	7,027	117.1	807	13.4
RWY 6R	8,778	146.3	3,688	61.5
OP 1	1,947	32.5	0	0.0
OP 2	0	0.0	0	0.0
OP 3	2,392	39.9	0	0.0
4-ATCT	0	0.0	0	0.0
OP 5	0	0.0	0	0.0

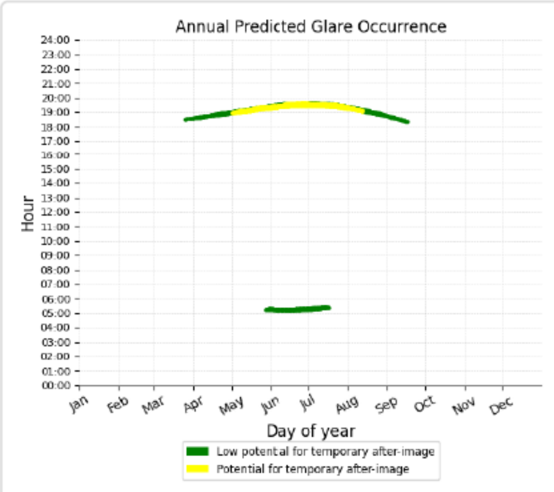
PV: PV array 1 potential temporary after-image

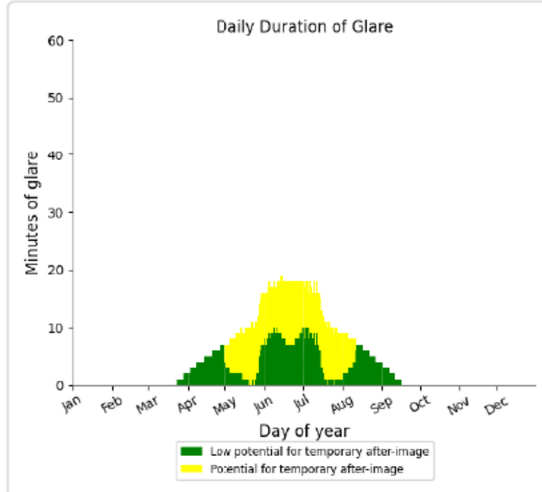
Receptor results ordered by category of glare

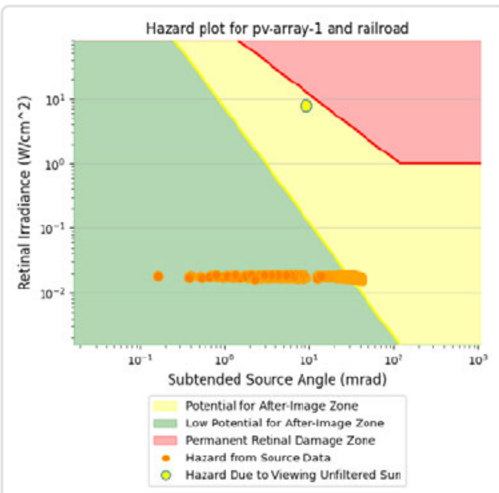
Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Railroad	785	13.1	869	14.5
State Route 2	0	0.0	0	0.0
W 3rd ST	0	0.0	0	0.0
W 9th ST	0	0.0	0	0.0
RWY 6L	7,027	117.1	807	13.4
RWY 6R	8,778	146.3	3,688	61.5
RWY 24L	81	1.4	0	0.0
RWY 24R	0	0.0	0	0.0
OP 1	1,947	32.5	0	0.0
OP 3	2,392	39.9	0	0.0
OP 2	0	0.0	0	0.0
4-ATCT	0	0.0	0	0.0
OP 5	0	0.0	0	0.0

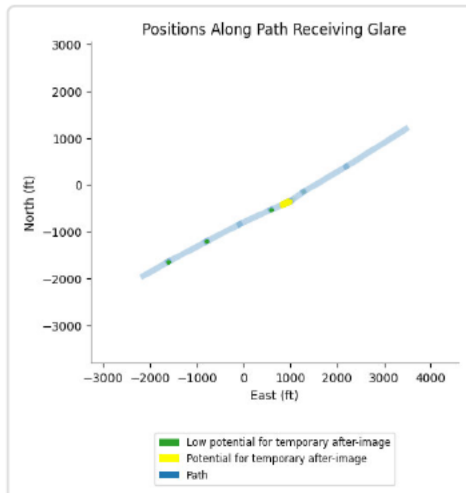
PV array 1 and Route: Railroad

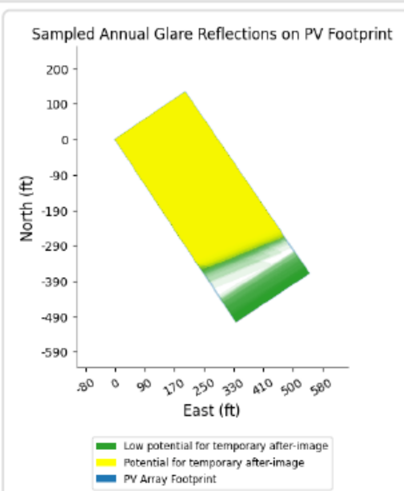
Yellow glare: 869 min.
Green glare: 785 min.











PV array 1 and Route: State Route 2

No glare found

PV array 1 and Route: W 3rd ST

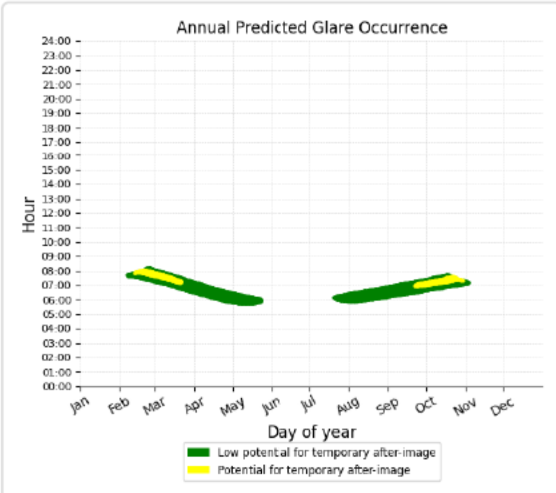
No glare found

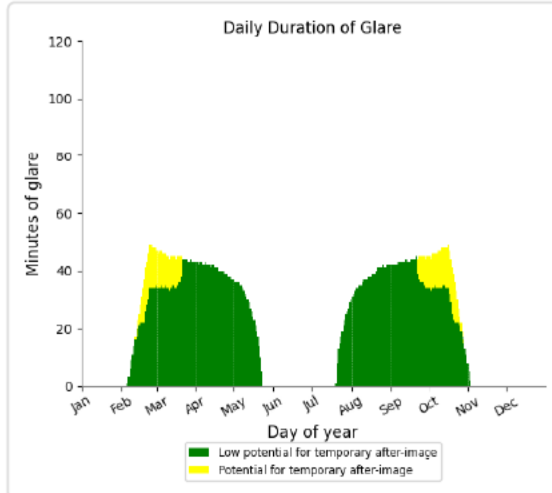
PV array 1 and Route: W 9th ST

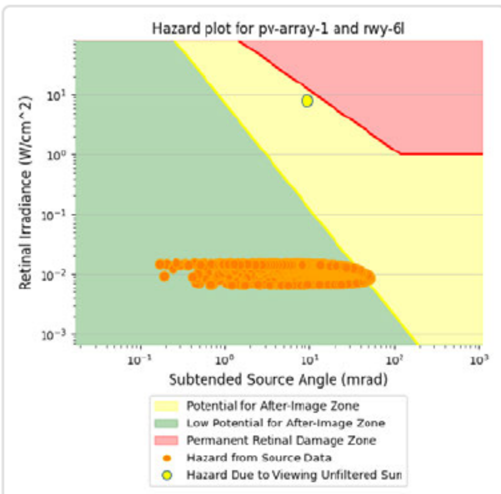
No glare found

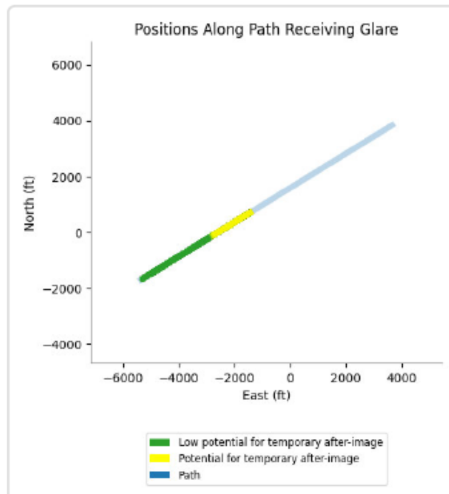
PV array 1 and FP: RWY 6L

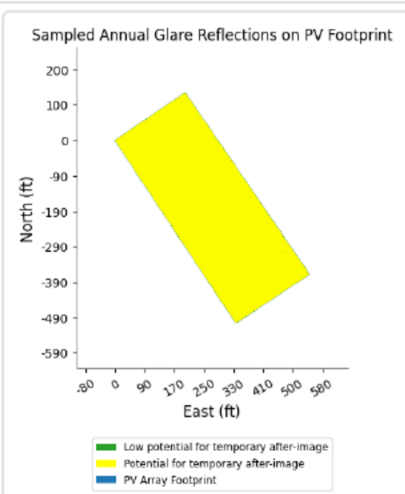
Yellow glare: 807 min.
Green glare: 7,027 min.

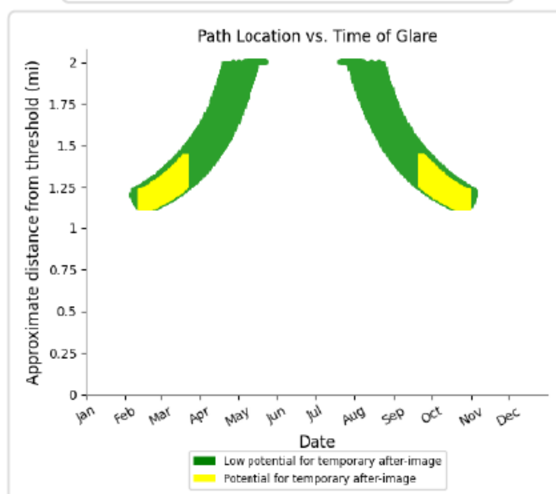






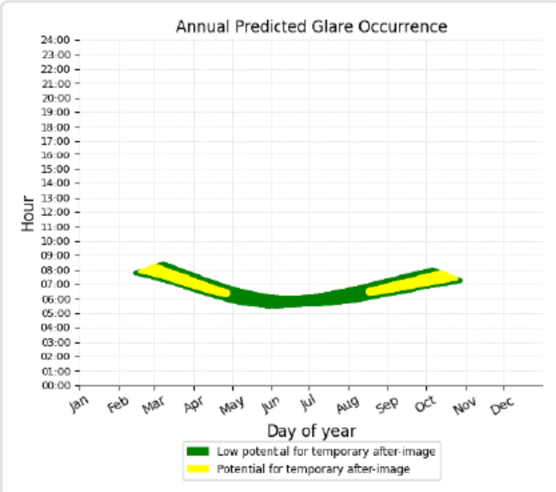


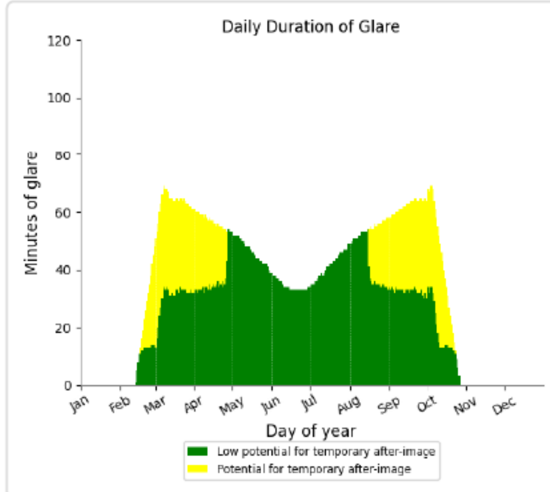


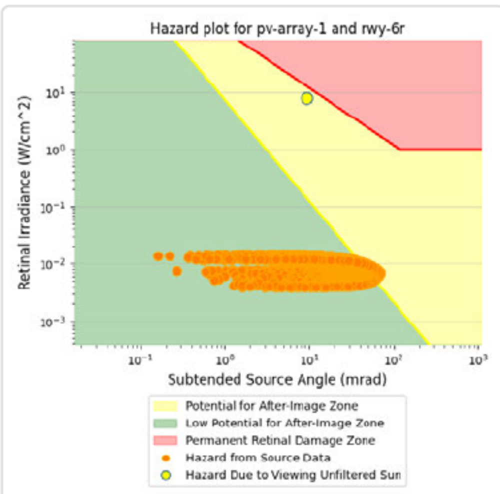


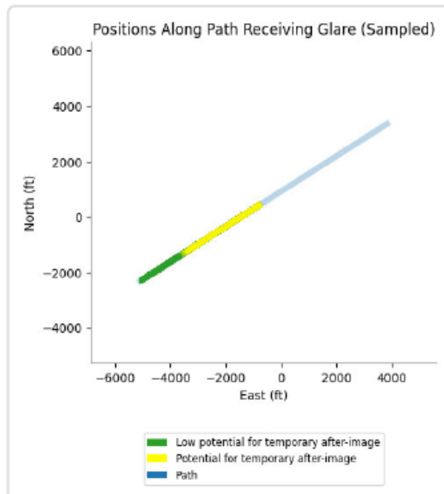
PV array 1 and FP: RWY 6R

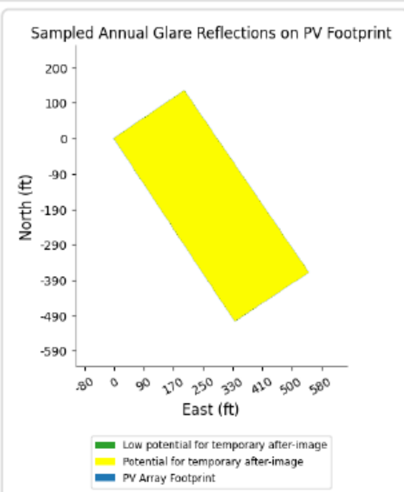
Yellow glare: 3,688 min.
Green glare: 8,778 min.

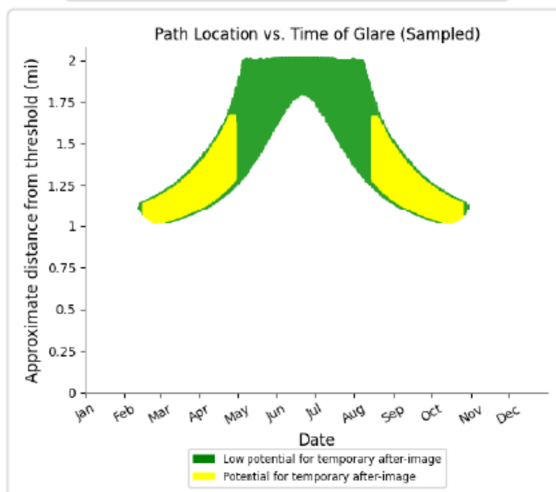






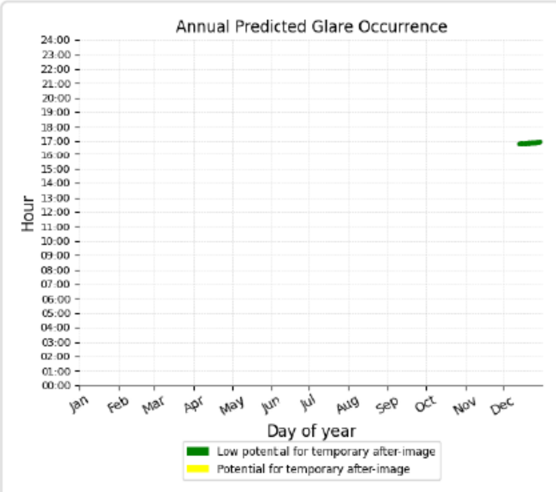


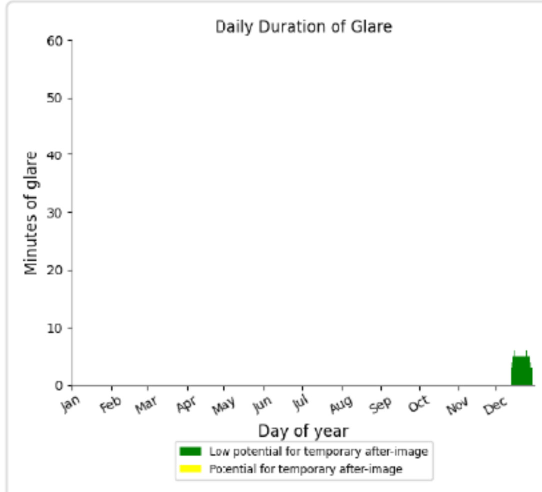


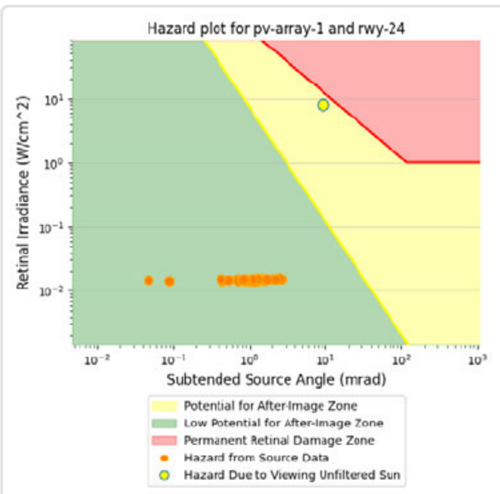


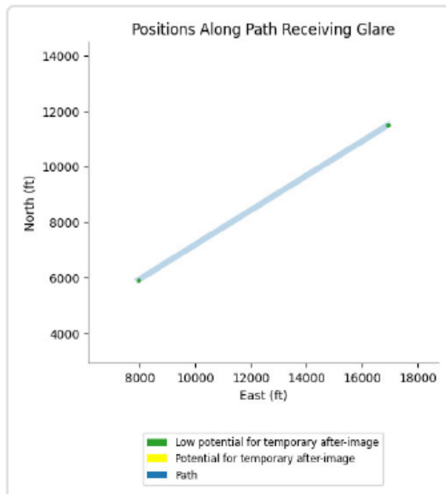
PV array 1 and FP: RWY 24L

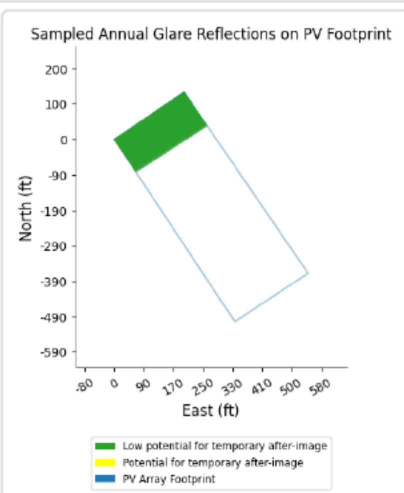
Yellow glare: none
Green glare: 81 min.

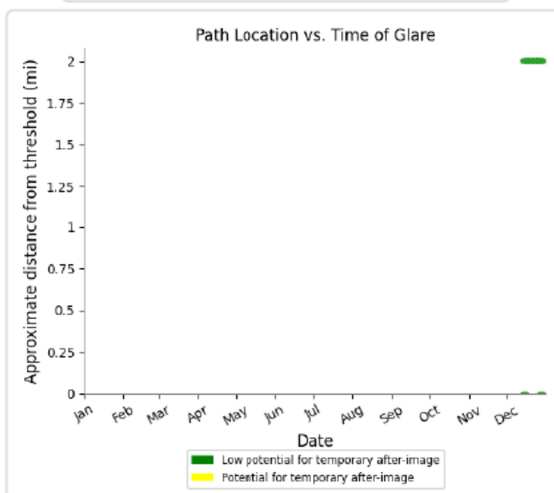










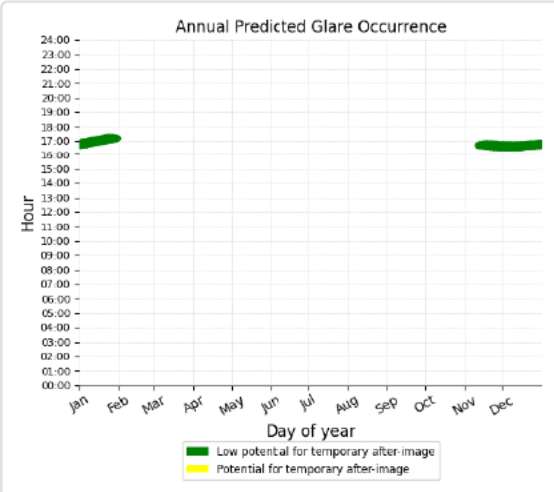


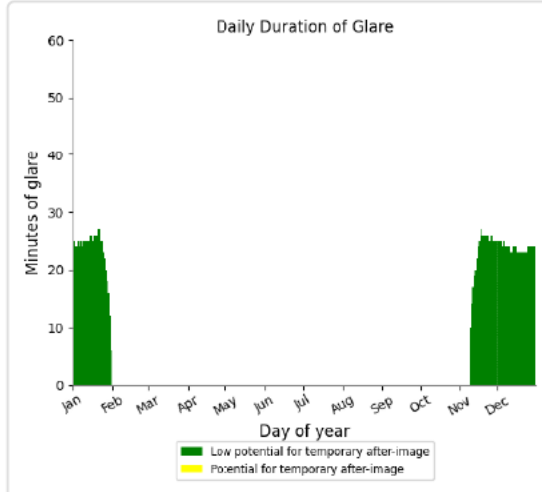
PV array 1 and FP: RWY 24R

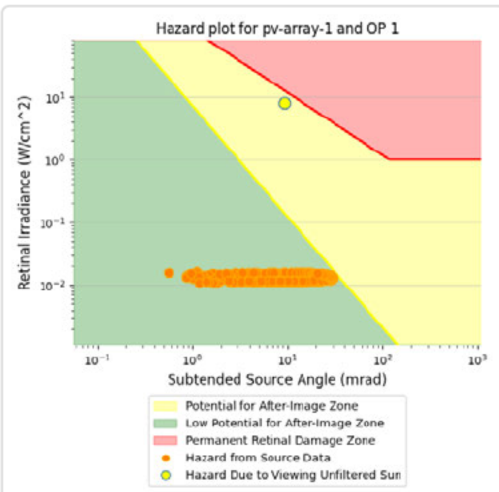
No glare found

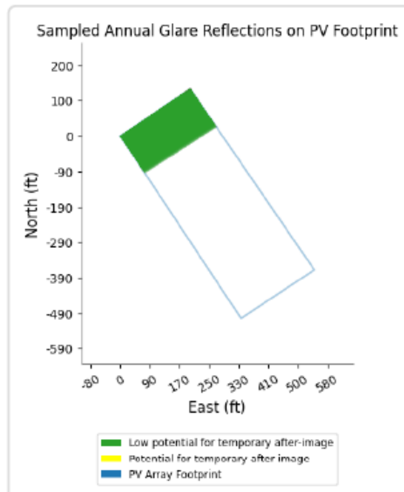
PV array 1 and OP 1

Yellow glare: none
Green glare: 1,947 min.



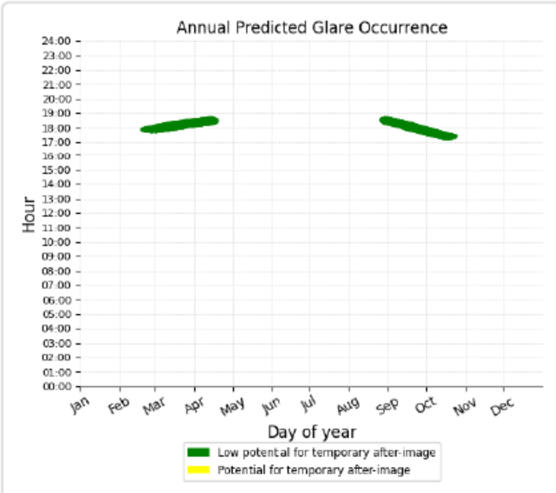


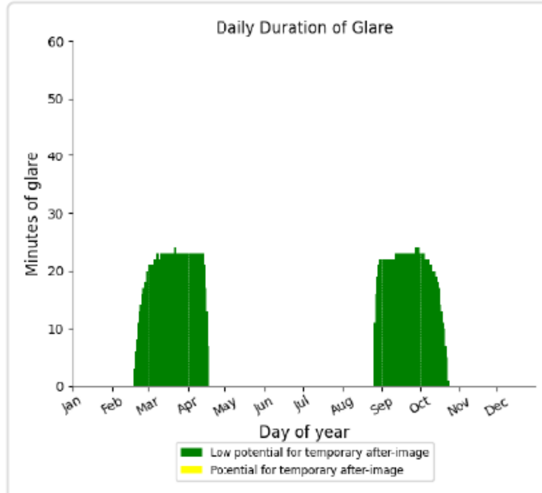


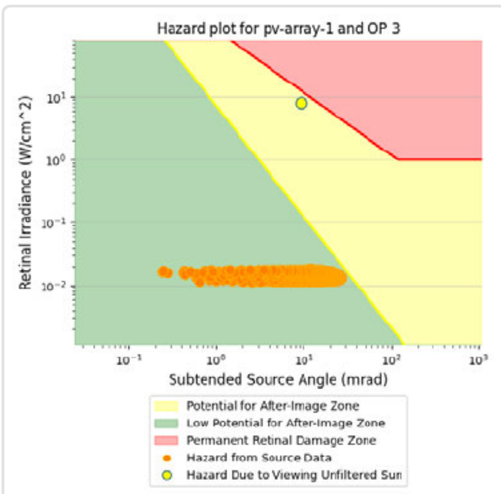


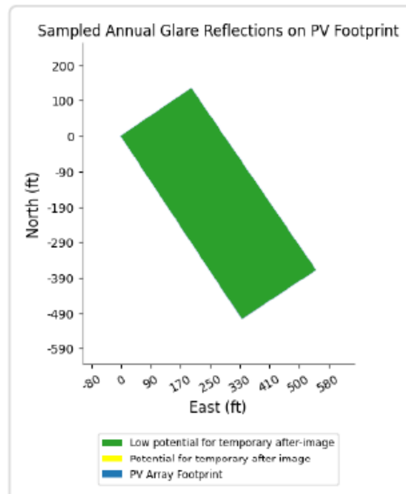
PV array 1 and OP 3

Yellow glare: none
Green glare: 2,392 min.









PV array 1 and OP 2

No glare found

PV array 1 and 4-ATCT

No glare found

PV array 1 and OP 5

No glare found

Assumptions

"Green" glare is glare with low potential to cause an after-image (flash blindness) when observed prior to a typical blink response time.
"Yellow" glare is glare with potential to cause an after-image (flash blindness) when observed prior to a typical blink response time.
Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
The algorithm does not rigorously represent the detailed geometry of a system; detailed features such as gaps between modules, variable height of the PV array, and support structures may impact actual glare results. However, we have validated our models against several systems, including a PV array causing glare to the air-traffic control tower at Manchester-Boston Regional Airport and several sites in Albuquerque, and the tool accurately predicted the occurrence and intensity of glare at different times and days of the year.
Several V1 calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results for large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare. This primarily affects V1 analyses of path receptors.
Random number computations are utilized by various steps of the annual hazard analysis algorithm. Predicted minutes of glare can vary between runs as a result. This limitation primarily affects analyses of Observation Point receptors, including ATCTs. Note that the SGHAT/ ForgeSolar methodology has always relied on an analytical, qualitative approach to accurately determine the overall hazard (i.e. green vs. yellow) of expected glare on an annual basis.
The analysis does not automatically consider obstacles (either man-made or natural) between the observation points and the prescribed solar installation that may obstruct observed glare, such as trees, hills, buildings, etc.
The subtended source angle (glare spot size) is constrained by the PV array footprint size. Partitioning large arrays into smaller sections will reduce the maximum potential subtended angle, potentially impacting results if actual glare spots are larger than the sub-array size. Additional analyses of the combined area of adjacent sub-arrays can provide more information on potential glare hazards. (See previous point on related limitations.)
The variable direct normal irradiance (DNI) feature (if selected) scales the user-prescribed peak DNI using a typical clear-day irradiance profile. This profile has a lower DNI in the mornings and evenings and a maximum at solar noon. The scaling uses a clear-day irradiance profile based on a normalized time relative to sunrise, solar noon, and sunset, which are prescribed by a sun-position algorithm and the latitude and longitude obtained from Google maps. The actual DNI on any given day can be affected by cloud cover, atmospheric attenuation, and other environmental factors.
The ocular hazard predicted by the tool depends on a number of environmental, optical, and human factors, which can be uncertain. We provide input fields and typical ranges of values for these factors so that the user can vary these parameters to see if they have an impact on the results. The speed of SGHAT allows expedited sensitivity and parametric analyses.
The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.
Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid based on aggregated research data. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
Refer to the Help page at **www.forgesolar.com/help/** for assumptions and limitations not listed here.

Default glare analysis parameters and observer eye characteristics (for reference only):

- Analysis time interval: 1 minute
- Ocular transmission coefficient: 0.5
- Pupil diameter: 0.002 meters
- Eye focal length: 0.017 meters
- Sun subtended angle: 9.3 milliradians