



**CALIFORNIA
ENERGY COMMISSION**



California Energy Commission
Clean Transportation Program

FINAL PROJECT REPORT

The Sustainable Power Advancement and Resiliency for Our Community Blueprint Project

Prepared for: California Energy Commission

Prepared by: Oxnard Harbor District – The Port of Hueneme



March 2026 | CEC-600-2026-010

California Energy Commission

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PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation Program. The statute authorizes the California Energy Commission (CEC) to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) reauthorizes the Clean Transportation Program through January 1, 2024, and specifies that the CEC allocate up to \$20 million per year (or up to 20 percent of each fiscal year's funds) in funding for hydrogen station development until at least 100 stations are operational.

The Clean Transportation Program has an annual budget of about \$100 million and provides financial support for projects that:

- Reduce California's use and dependence on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.
- Produce sustainable alternative and renewable low-carbon fuels in California.
- Expand alternative fueling infrastructure and fueling stations.
- Improve the efficiency, performance and market viability of alternative light-, medium-, and heavy-duty vehicle technologies.
- Expand the alternative fueling infrastructure available to existing fleets, public transit, and transportation corridors.
- Establish workforce-training programs and conduct public outreach on the benefits of alternative transportation fuels and vehicle technologies.

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the CEC's annual Clean Transportation Program Investment Plan Update. The CEC issued GFO-20-601 to provide funding for the planning of conversion of MDHD fleets to zero emission. In response to GFO-20-601, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards April 8, 2021, and the agreement was executed as ARV-21-024 on September 14, 2021.

ABSTRACT

This paper summarizes the Sustainable Power Advancement and Resiliency for Our Community blueprint project, which analyzed cargo handling equipment operations at the Port of Hueneme to determine the best mix of technologies for a transition to zero emission. Battery electric and hydrogen fuel cell alternatives were the primary two technologies considered. Alternatives were considered based on their ability to perform in the operating environment, operating cost, capital cost, and availability for deployment. Requirements and the basis were derived based on interviews with operators, as well as equipment utilization analysis based on cargo volumes and equipment duty cycles. Key stakeholders within the community were engaged throughout the process to integrate their input and share the key findings of the planning effort.

Based on the duty cycles, which are limited by the capacity of vessels that call on the port, battery electric was determined to be the optimal technology for cargo handling equipment deployments. With a higher technology readiness level than hydrogen cargo handling equipment, and a lower operating cost based on the relative cost of grid electricity and hydrogen, battery electric cargo handling equipment represents a commercially viable path to zero. The primary constraint is the timeline for expanding the current utility service to meet the growing power demands of the facility as zero emission cargo handling equipment is integrated at a commercial scale, along with shore power and other future loads. Funding will also be important to support infrastructure and operator equipment deployments.

Based on the findings from the analysis performed, converting all cargo handling equipment to zero emission alternatives by 2030 is attainable. Along with currently planned shore power and emissions capture systems for ocean-going vessels, this will address the port's largest sources of air pollutants, with the exception of harbor craft, rail, and drayage trucking.

Keywords: air, battery, California, cargo, cell, charging, commercial, cost, electric, emission, energy, environmental, equipment, harbor craft, Hueneme, hydrogen, infrastructure, port, technology, zero emission

Please use the following citation for this report:

Kemper, Jordan, Christopher Hussey. 2026. *The SPARC Blueprint Project*. California Energy Commission. Publication Number: CEC-600-2026-010.

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EXECUTIVE SUMMARY

The Sustainable Power Advancement and Resiliency for Our Community blueprint examined equipment and infrastructure technologies to enable a conversion of all cargo handling equipment operations to zero emission. Hydrogen fuel cell and battery electric alternatives were explored and evaluated against operational requirements at the port, in addition to commercial and technology readiness considerations.

Operational data for required analysis was limited, necessitating the development of a utilization model based on vessel call data and operator input. This allowed the project team to determine the energy usage of equipment over time and identify infrastructure requirements accordingly. Equipment utilization is driven by cargo volume, which is driven by vessel size. The Port of Hueneme's berths constrains the vessel sizes that can make calls to smaller vessels compared to some ports. This means that operators in the Port of Hueneme will be able to perform operations using battery electric alternatives, which are commercially available, already being deployed on the property, and offer operational cost savings. Fuel cell cargo handling equipment alternatives are not required or recommended at this time due to lower commercial readiness and higher relative cost. The exceptions to this are leveraging fuel cell technology for stationary power, rail, and maritime applications, as well as select heavy lift equipment.

The port can feasibly transition to zero emission cargo handling equipment operations with a 2030 goal by taking a lead in developing charging infrastructure to support current and future fleets. Due to the unique nature of operations at the Port of Hueneme, it is recommended that the port own and deploy the proposed charging infrastructure to ensure fair, timely access to infrastructure for all commercial partners. It is important that the port control infrastructure siting and technology selection to avoid stranded asset risk and establish clear standards for use. Additionally, the integration of climate change adaptation considerations such as stormwater intrusion and sea level rise are suggested for future infrastructure deployments.

Current electrical service is not sufficient for future charging infrastructure requirements. The port will need to prioritize engagement with Southern California Edison Company to support electrical service upgrades necessary for planned infrastructure implementation. In parallel, the implementation of new policies and commercial incentives will help align the port with its commercial partners to support adoption and commercial-scale deployment. It is recommended that the port leverage both battery electric and hydrogen-based energy storage systems to improve resiliency, provide stationery power, enable load shifting, and support charging systems.

Harbor craft were not examined closely in this report as the best commercially available emissions control technology is currently Tier 4 diesel, and the port's commercial partner plans to adopt Tier 4 during their next repower. Fuel cell alternatives are promising for zero-emission harbor craft, but infrastructure is lacking and technology is still under development. Ocean going vessel emission control technologies, including an emission capture barge and shore power, are already currently deployed or in planning phases for upcoming deployments.

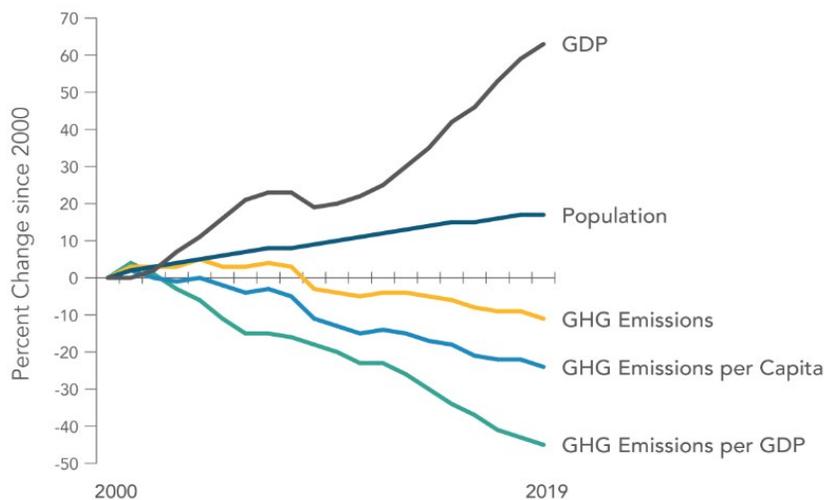
CHAPTER 1:

Regional Environmental Goals

The State of California has set several aggressive environmental goals that are relevant to the Port of Hueneme’s (or port) operations and planning efforts. These goals help shape policy on a state level and are important to consider as the port sets its own environmental goals and policies. The California Air Resources Board (CARB) is the clean air agency for the government of California. It is charged with protecting the public from the harmful effects of air pollution and developing programs and actions to fight climate change. Its programs and goals address harmful air pollutants ranging from toxic air contaminants to greenhouse gas (GHG) emissions.¹

Assembly Bill 32, the Global Warming Solutions Act of 2006, is a key policy measure California enacted to reach 1990 greenhouse gas levels by 2020 (15 percent reduction from business-as-usual scenario).² CARB instituted several key policies and programs, including mandatory reporting for large emitters, the Air Toxics Program, the Diesel Risk Reduction Plan, and many others that have set a consistent pace for ramping up air quality standards. CARB updates its scoping plan on a five-year basis, outlining the state’s strategy for meeting its goals. Figure 1 shows the percent change in GHG emissions, gross domestic product, and population growth from 2000 to 2019.

Figure 1: Percent Change of GHG Emissions in Correlation to GDP and Population Growth (2000-2019)



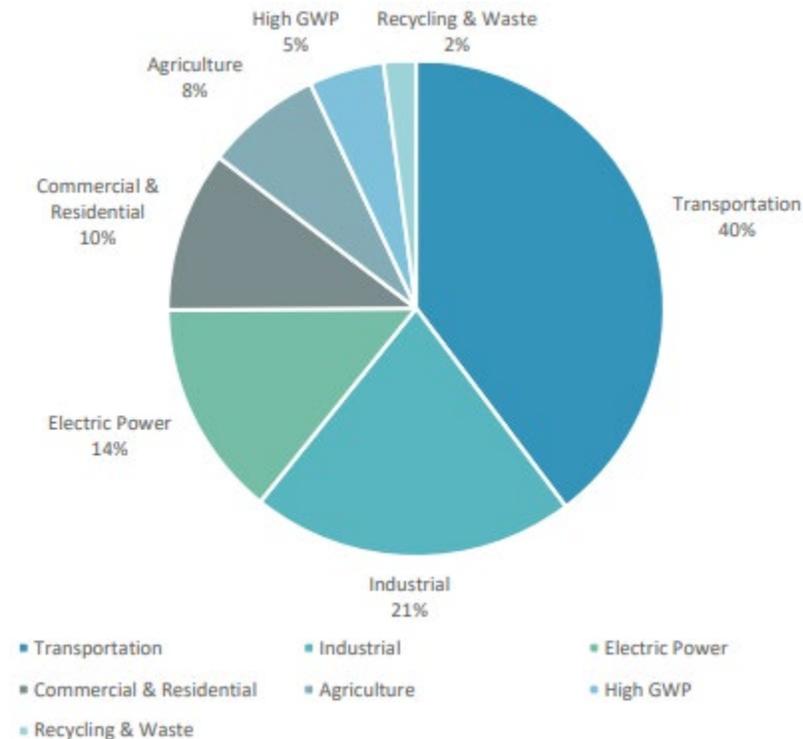
Credit: *California Air Resources Board*

¹ [California Air Resources Board website](https://ww2.arb.ca.gov/about) (https://ww2.arb.ca.gov/about)

² [California Legislative Information website for Assembly Bill 32](https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200520060AB32) (https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200520060AB32)

The 2017 scoping plan outlined the state plan to reach its 2030 climate target to reduce GHG emissions by 40 percent from 1990 levels and advance toward the 2050 goal to reduce GHG emissions by 80 percent below 1990 levels. CARB published its draft scoping plan for 2022 on May 10, 2022, highlighting a carbon neutrality goal of 2045. Special emphasis is placed on the industrial, electric power, and transportation sectors as they constitute a combined 75 percent of State GHG emissions in the 2019 year (Figure 2).

Figure 2: Apportioned Emissions by Sector.



Credit: *California Air Resources Board*

Federal clean air laws require the development of state implementation plans (SIP) for all areas with unhealthy levels of ozone, inhalable particulate matter, carbon monoxide, oxides of nitrogen (NOx), and oxides of sulfur (SOx). A SIP describes how a region will meet national ambient air quality standards. Ventura County has been struggling to achieve those goals for ozone in recent years. The state’s 2022 SIP highlights increasing commitments to target air quality issues that present health risks to disadvantaged communities. Below is a summary of the key strategy measures proposed by the state.

Port of Hueneme Environmental History

The port has enacted several policies and programs throughout its history to advance its environmental goals. Implemented in 2012, the port’s environmental management framework (EMF) marked the beginning of the port’s strong push to become a national leader in maritime sustainability. This robust environmental document sets strategic action plans in these core areas:

- Air quality management
- Marine resources management
- Soil and sediment management

- Water quality management
- Energy management
- Climate change adaptation

In 2016, the port became the first port in California to become certified by Green Marine, an international environmental certification program for maritime facilities. Green Marine helps to guide the integration of sustainability into the port's day-to-day operations.

In recent years, the port has focused on addressing the challenge of the climate crisis and the intersection between air quality, energy management and climate change adaptation, and has become a regional leader in industrial decarbonization and community air quality. Central among those efforts are its air quality monitoring and emissions inventory efforts. These provide critical data to measure the effectiveness of emissions mitigation efforts such as the electrification of port equipment.

Starting in 2018, the port has produced regular emissions inventory reports to track its progress, using emissions estimates for 2008 as its baseline. Over the 12-year period from 2008 to 2020, the port has seen an 85 percent reduction in diesel particulate matter, a 37 percent reduction in NO_x, a 97 percent reduction in SO_x, and a 7 percent reduction in, all while experiencing a 25 percent growth in cargo volume.

In 2019, the port commenced its community air quality monitoring program, with the installation of United States Environmental Protection Agency reference grade monitoring equipment at local Haycox Elementary School, located about 1.5 kilometers east of the port. The monitoring station measures particulate matter and black carbon as a surrogate for diesel particulate matter, providing community-specific air quality data to local stakeholders.

The port's environmental management framework defined several key long-term strategies relevant to the blueprint that are in preliminary development. The first of note is the Green Lease Program, intended to incorporate new language to support periodic review of new technologies, and assess the cost, technical feasibility, and operational feasibility of new technologies. The second is a Technology Advancement Program that is designed to provide incentive funding for accelerating the implementation of zero emissions equipment and infrastructure. Air quality key performance indicators identified in the port's environmental management framework are a reduction in criteria pollutants (carbon monoxide, oxides of nitrogen, particulate matter less than 10 microns (PM₁₀), SO_x, total hydrocarbon, carbon dioxide, methane, and nitrous oxide).

An electrical master plan for the port was produced in 2019 by electrical engineering firm H3 Engineering. The plan, which is a living document updated on a regular basis, takes a close look at the port's electrical infrastructure and estimates future loads based on electrification scenarios. The plan highlights opportunities for the potential deployment of electric top handlers, 10 additional electric utility tractor rigs (UTRs), and the possible deployment of a rack system to support refrigerated containers, which would necessitate an increase in container handlers such as reach stackers. Additionally, the report explores the electrification of up to six dock cranes, each with an estimated power requirement of 720 kilowatts (kW).

The port's investments and leadership in environmental stewardship to date have earned it several awards and recognition over the years. In 2016, the Port of Hueneme became the first port in the State of California to receive a Green Marine Certification. The port was also given high accolades during the 2017 US Green Shipping Summit as the Greenest Port of the Year.

Additionally, the Ventura County Board of Supervisors presented the port with an Award for Excellence in Environmental Stewardship in 2017 on Earth Day.

The port has also proactively begun the development of a clean air action plan in partnership with the local air quality regulatory agency, the Ventura County Air Pollution Control District. The *Port of Hueneme, Reducing Emissions, Supporting Health Plan* will be the first time in the state that a port and its air quality regulator have teamed up to write a clean air plan together. The plan will assess and address the port’s emissions, air quality requirements and goals for the port, future growth scenarios, emission control strategies, community involvement, strategy funding, implementation, and monitoring.

In 2021, the port’s Board of Harbor Commissioners unanimously approved a resolution committing to the decarbonization of its operations. A goal has been set for all port trucking to be zero-emission by at least 2035 for short haul and drayage and at least 2045 for long haul. Additionally, the board committed to additional reductions of ocean-going vessel emissions via the at-berth regulations by 2025 or sooner, including auto carriers and roll-on/roll-off vessels. In 2024, the Port of Hueneme kicked off its *Clean Air Action Plan*, to further expand on climate adaptation and contribution efforts under a unified program. This action plan will integrate and expand upon findings from the blueprint and help prepare the port for challenges presented by climate change such as sea level rise and stormwater inundation.

Equipment Inventory

The equipment inventory in Table 1 was provided as a basis in 2022 for evaluating replacement equipment. The predominant cargo handling equipment (CHE) utilized on the property is a utility tractor rig (UTR), which is used to move containers around the terminal and lay them on chassis. The port also uses reach stackers and several different classes of heavy-duty forklifts to move cargo. The port does not currently stack containers. It operates on a chassis model, improving cargo velocity and reducing the need for a larger number of laden container handlers. This may change over the coming decade to further increase the container capacity of the terminal. Due to expected growth in volume and CHE over the coming decade, infrastructure will be designed to support a larger fleet.

Table 1: Equipment Inventory

Port Equipment Inventory			Equipment Specifications				
QTY	Engine Year	Model	Equipment Type	Engine Type	Name Engine Index	Engine Model	HP
1	2015	4x2 DOT EPA	UTR	Diesel	UTR, Diesel	B6.7 200	200
3	2019	4x2 DOT EPA	UTR	Diesel	UTR, Diesel	B6.7 200	200
13	2013	4x2 DOT EPA	UTR	Diesel	UTR, Diesel	B6.7 200	200
1	2015	YT223	UTR	Diesel	UTR, Diesel	B6.7 225	225
1	2019	YT223	UTR	Diesel	UTR, Diesel	B6.7 225	225
4	2020	YT223	UTR	Diesel	UTR, Diesel	B6.7 225	225

1	2009	TJ6000	UTR	Diesel	UTR, Diesel	QSBT4F 6.7L 225	225
2	2020	T2E+	UTR	Electric	UTR, Diesel	Power Drive 8000	244
1		H300	Forklift - Class V	Diesel	Forklift - Class V, Diesel	QSB 6.7L 156	156
1		H190-280XD	Forklift - Class V	Diesel	Forklift - Class V, Diesel	QSB 6.7L 156	156
1	2005	H50FT	Forklift - Class V	Propane	Forklift - Class V, Propane	PSI 2.4L	59
1	2003	LMH320	Mobile Harbor Crane	Diesel	Mobile Harbor Crane, Diesel	D 444.901-505	677
1	2016	LMH420	Mobile Harbor Crane	Diesel	Mobile Harbor Crane, Diesel	D 2842 LE	1085
1	2020	LMH420e	Mobile Harbor Crane	Hybrid	Mobile Harbor Crane, Hybrid	D 9512 A7	765
1		HTC-238H	Truck Mounted Crane	Diesel	Truck Mounted Crane, Diesel	6SD1TQB	207
1		HC-238A	Truck Mounted Crane	Diesel	Truck Mounted Crane, Diesel	6V-92TAC	260
2	1991	DC25-1200	Forklift - Class V	Diesel	Forklift - Class V, Diesel	TD71AW	200
2	1996	DC13-600XL	Forklift - Class V	Diesel	Forklift - Class V, Diesel	P-1006	129
1	2013	RS 46XD	Container Handler	Diesel	Container Handler, Diesel	X12 380	380
1	2015	RS 46XD	Container Handler	Diesel	Container Handler, Diesel	X12 380	380
1	2018	RS 46XD	Container Handler	Diesel	Container Handler, Diesel	X12 380	380
1	2017	Unknown	Towing Vessel	Diesel	Towing Vessel, Diesel	3512C	2375
1	2013	Unknown	Towing Vessel	Diesel	Towing Vessel, Diesel	3512C	2000

Source: *Zero Emission Advisors*

CHAPTER 2:

Technical and Economic Feasibility for Battery and Fuel Cell Technologies

The Sustainable Power Advancement and Resiliency for Our Community Blueprint (SPARC) examined equipment and infrastructure technologies to enable a conversion of all CHE operations to zero emission. Hydrogen fuel cell and battery electric alternatives were explored and evaluated against operational requirements at the port, in addition to commercial and technology readiness considerations.

Operational data for required analysis was limited, necessitating the development of a utilization model based on vessel call data and operator input. This allowed the project team to determine the energy usage of equipment over time and identify infrastructure requirements accordingly. Equipment utilization is driven by cargo volume, which is driven by vessel size. The Port of Hueneme's berths constrains the vessel sizes that can make calls to smaller vessels compared to some ports. This means that operators in the Port of Hueneme will be able to perform operations using battery electric alternatives, which are commercially available, already being deployed on the property, and offer operational cost savings. Fuel cell CHE alternatives are not required or recommended at this time due to lower commercial readiness and higher relative cost. The exceptions to this are leveraging fuel cell technology for stationary power, rail, and maritime applications, as well as select heavy lift equipment.

Methodology

Port equipment quantitative analysis methodology is discussed below for each of the equipment categories and is referred to as methodology. All port equipment and electricity use was viewed as energy load in terms of kilowatts, kilowatt-hours (kWh), and kilograms of hydrogen, including gas and diesel engines. Emissions were derived as a function of energy (fnc) use: emissions = fnc (kWh). To find this relationship, energy use and emissions were used from a report published by Starcrest Consulting, and then a constant (*C) was created and solved to formulate: emissions = *C x kWh. Then, when varied solutions are presented to decrease energy use, in kWh, from hydrocarbon fuels, the quantity of reduced emissions is found easily.

The emissions tracked were CO₂e, PM₁₀, and NO_x. CO₂e was considered an imperative to quantify the climate impact, with PM₁₀ being a close second. On a global scale, particulate matter lands on glaciers making them darker, decreasing their albedo, and making them melt faster. PM₁₀ also has grave effects on human health as a local pollutant. Finally, NO_x is another important local pollutant and is the only pollution product of burning ammonia in an internal combustion engine. Given that ocean going vessels may someday run on ammonia, and that ammonia is a hydrogen carrier molecule, NO_x was tracked. Below is a discussion of each equipment type and the energy use and emissions metrics of each; the methodology specific to each equipment type is also detailed.

Core Technologies Examined

Battery Electric Technologies

Battery-electric medium-duty and heavy-duty (MDHD) equipment is a rapidly growing market, with demonstration projects and commercial-scale deployments in port applications worldwide. In many cases, these technologies are slightly more mature in commercialization compared to hydrogen alternatives, though they can struggle where weight, available infrastructure capacity, or energy storage become an issue.

The global demand for battery electric technologies is growing at an exponential rate, driven mainly by the demand for electric mobility and energy storage solutions. Government and commercial stakeholders have committed to deploying battery-electric zero-emission vehicles to perform a range of activities, though initial growth in battery manufacturing capacity was driven by light-duty vehicles.

“Global battery demand doubled in 2021, driven by electric car sales in China,” according to a 2022 International Energy Agency (IEA) report on the global electric vehicle (EV) market³. Pressures on the supply chain present serious bottlenecks for meeting global demand. Metal commodity price surges are expected to have an adverse impact on battery prices while promoting greater diversification in battery chemistries. The IEA estimated that if metal prices remained consistent from the first quarter of 2022 for the remainder of the year, battery pack prices could increase by up to 15 percent from 2021 figures.

Hydrogen Fuel Cell Technologies

Another zero emission powertrain option is the hydrogen fuel cell. Originally invented over 100 years ago, and largely developed by the National Aeronautics and Space Administration (NASA) for use in the Apollo space missions of the 1960s, hydrogen fuel cells are today used to provide zero emission electricity on applications that typically require a large amount of onboard energy storage and fast refueling options.

The most common type of fuel cell utilized in mobility applications is a proton-exchange membrane fuel cell, which offers the best combination of power density, efficiency, and efficiency for MDHD equipment like CHE, commercial marine vessels, and trucks. These systems are ideally suited for applications in environments with limited grid capacity for charging, or where the limitations of battery-energy storage prohibit sufficient endurance. They often utilize compressed gas tanks at a fill pressure of up to 700 BAR.

Major equipment original equipment manufacturers (OEM) like Taylor and Hyster are developing and testing heavy lift fuel cell electric vehicles (FCEVs) all around the world. Ballard Power Systems, a leading manufacturer of fuel cells for several markets, reported a 65 percent reduction in the price of fuel cell vehicles over the last ten years. Major truck OEMs are developing Class 8 FCEVs and promoting the development of infrastructure for the market. Companies like Zero Emission Industries are building fuel cell power systems for commercial maritime applications.

Access to fuel is essential for supporting early demonstration projects and commercial-scale deployments. For many heavy-duty applications, the fuel cost represents a significant portion of the overall operating cost and total cost of ownership. According to Ballard Power systems,

³ [International Energy Agency staff. 2022. *Global Supply Chains of EV Batteries*. \(https://www.iea.org/reports/global-supply-chains-of-ev-batteries\)](https://www.iea.org/reports/global-supply-chains-of-ev-batteries)

the reduction in the cost of producing green hydrogen has been forecasted to drop below \$1.00 per kilogram by 2050.⁴

Cargo Handling Equipment

There have been several recent advancements in the development of zero emission alternatives for CHE. Multiple demonstration projects and commercial-scale deployments have been completed or are presently underway by OEMs such as Taylor, Orange EV, Kalmar, Hyster and Wiggins Lift. There is a range of technologies being explored as alternatives to diesel by OEMs, including battery-electric, hybrid, propane, hydrogen fuel cells, and natural gas based solutions. Due to the increasing availability of zero emission alternatives at an adequate technology readiness level (TRL) within the planning horizon, bridge fuels or near-zero alternatives were not considered, only zero emission technologies.

Methodology - CHE

Requirements for CHE were derived by generating a utilization model based on vessel call data and input from the operators. Shift structures were defined through interviews with the operators, and assigned against vessel schedules to produce a higher-resolution dataset on time of use and energy consumption. This analysis was a critical step as current data on CHE utilization was limited to annualized totals, which would not provide sufficient detail time of use needed to determine if certain CHE alternatives could achieve a full work shift. An energy consumption and utilization profile was generated that was representative of the high-intensity work shift, to ensure that the most intense duty cycles were accounted for. This energy model allowed the project team to compare various charge rates, zero-emission CHE alternatives and determine what would be operationally viable within the Port of Hueneme's unique operating environment.

Technologies were assessed along several factors to determine suitability for adoption. The first is the TRL, originally developed by NASA and presently utilized by the United States Department of Energy. TRL provides a standard metric from 1-9 used by governments and commercial entities to determine the maturity of a given technology (Figure 3). Generally, technologies will only be considered in near-term planning if they have achieved a TRL of 6-7 or greater.

⁴ [Ballard Power Systems staff and Deloitte China staff. 2021. *Fueling the Future of Mobility: Hydrogen and Fuel Cell Solutions for Transportation*.](https://www2.deloitte.com/content/dam/Deloitte/cn/Documents/finance/deloitte-cn-fueling-the-future-of-mobility-en-200101.pdf)
(<https://www2.deloitte.com/content/dam/Deloitte/cn/Documents/finance/deloitte-cn-fueling-the-future-of-mobility-en-200101.pdf>)

Figure 3: Technology Readiness Breakdown

Technology Readiness Levels

Relative Level of Technology Development	Technology Readiness Level	Definition
System Operations	TRL 9	Actual system operated over the full range of expected conditions.
System Commissioning	TRL 8	Actual system completed and qualified, through test and demonstration.
	TRL 7	Full-scale, similar (prototypical) system demonstrated in relevant environments.
Technology Demonstration	TRL 6	Engineering/pilot-scale similar (prototypical) system validation in relevant environments.
	TRL 5	Laboratory scale; similar system validation in relevant environment.
Technology Development	TRL 4	Component and/or system validation in laboratory environment.
	TRL 3	Analytical and experimental critical function and/or characteristic proof of concept.
Research to Prove Feasibility	TRL 2	Technology concept and/or application formulated.
Basic Technology Research	TRL 1	Basic principles observed and reported.

Credit: *Zero Emission Advisors*

The second metric used is the commercial readiness level (CRL), which operates on a scale of 1-6 and addresses various factors influencing commercial market factors as opposed to the maturity of a given technology. CRL presents an evolution from a highly subsidized, but technically viable solution, to a fully bankable asset (Figure 4). Because many of the technology adoptions at the port are made by operating tenants, not the Port of Hueneme itself, CRL provides a more valuable framework for evaluating the considerations of tenant adoption. Technologies with a CRL as low as 1 and 2 can be considered for early-stage demonstration projects but are unlikely to see rapid adoption by tenants for several years.

Figure 4: Commercial Readiness Breakdown

Commercial Readiness Index		
Relative Level of Commercial Readiness	Commercial Readiness Index Level	Definition
Bankable Grade Asset	6	Considered a "bankable" grade asset class with known standards and performance expectations. Market and technology risks not driving investment decisions.
Market Competition, Driving Widespread Deployment	5	Competition emerging across all areas of the supply chain. Verifiable data on technical and financial performance in the public domain
Multiple commercial applications.	4	Becoming evident locally; still subsidized. Verifiable data on technical and financial performance in the public domain, driving interest from a variety of debt and equity sources. Still requires government support, and faces regulatory challenges which are addressed in multiple jurisdictions.
Commercial Scale-Up	3	Small scale: first of a kind project funded by equity and government project support.
Commercial Trial	2	Commercial proposition backed by evidence of verifiable data; typically not in the public domain.
Hypothetical Commercial Proposition	1	Technically ready; commercially untested and unproven. Subsidized by the government.

Credit: *Zero Emission Advisors*

These two metrics combined provide valuable indicators of the stage of technical development and testing, as well as the readiness of the industry to support said technology with a robust, reliable supply chain. Together they provide a useful model for assessing the evolution from research and development to full commercialization. These two initial screening criteria are used to screen zero emission technologies and alternatives to ensure that considered technologies are commercially available and capable of performing CHE operations at the Port of Hueneme.

It’s important to note that these two metrics do not constitute final feasibility, but rather serve as initial acceptance criteria for further analysis. Additional criteria are considered for the final recommendation, including operational impact, infrastructure availability, and commercial viability.

Capital cost estimates are based on markup factors calculated by taking the average capital expenditure from listed studies and creating an average markup price factor per CHE category from a base diesel unit. Operational expenditure was calculated using the average hours per year provided by the port multiplied by operation and maintenance costs per hour. Fuel costs were derived from current commercial quotes specific to the Port of Hueneme region for the various fuel types (Table 2). Fuel costs, especially hydrogen are subject to change based on volume, offtake agreement term, and other factors. The hydrogen supply chain is still

immature and not to be considered a full commodity, resulting in a high variance in cost per kilogram. This is expected to improve, driving down the cost of hydrogen and reliability issues associated with the supply chain over the next five years.

Table 2: Fuel Cost Inputs

Fuel Type	Cost⁵
Diesel	\$5.69
Electricity (Commercial Rate)	\$0.12
Hydrogen	\$7.00
Propane	\$2.34
CNG	\$2.33
Gasoline	\$3.25
LNG	\$3.16

Source: *Zero Emission Advisors*

⁵ Fuel costs derived from current commercial quotes are specific to the Port of Hueneme region for various fuel types. Confirmed with local suppliers under the pretext of large scale commercial offtake agreement. Time period: first quarter 2023.

CHAPTER 3:

Engagement and Outreach Strategy

As a part of producing a blueprint, the Coalition for Clean Air (CCA) and Breathe Southern California (BSC) are subcontractors on the SPARC project with the goal of engaging stakeholders to provide input on the SPARC project. BSC and CCA sought stakeholder feedback from community members, including environmental organizations, public health organizations, government agencies, elected officials, business organizations, and labor representatives.

Stakeholder engagement was offered to interested parties in numerous ways, including participation in various roundtable meetings over Zoom, in-person meetings, opportunities to provide feedback in writing, and private meetings involving representatives from BSC and CCA and stakeholders. Translation was made available at several meetings, in both Spanish and Mixteco. The stakeholder engagement process was aimed to address the following key objectives:

- Establish criteria for identifying and prioritizing stakeholder groups,
- Identify strategies for effectively engaging all stakeholder groups in the SPARC project input process,
- Provide multiple opportunities and methods for stakeholders to provide input regarding the SPARC project,
- Establish iterative cycles of stakeholder engagement by identifying opportunities for ongoing feedback,
- Encourage transparency by ensuring stakeholders are aware of and informed about the overall process, especially stakeholder engagement.

The stakeholder engagement process was driven by the following guiding questions:

- What are the needs and concerns of each stakeholder group?
- What does a zero-emission Port of Hueneme mean to each stakeholder, and why is it important?
- How does a zero-emission Port of Hueneme benefit each stakeholder group?
- What concerns and opportunities do you see in bringing zero-emission technologies to the port?
- What would you like to see come out of this process?

In addition, the project partners used survey tools to ask participants at later meetings:

- What technologies are you most interested in seeing implemented?
- What outcomes do you want to see come out of a zero emission blueprint process

Broad Themes Across Stakeholder Groups

Some broad themes emerged throughout the various stakeholder engagement meetings, including:

1. The need to transition to zero emission technologies.

2. Collaborative partnerships.
3. Addressing the needs of the individuals who live and work in Ventura County.

Big Tent Meeting (in-person):

On August 4, 2023, CCA and BSC hosted the first so-called “Big Tent” meeting to present the findings from roundtable and one-on-one meetings and to continue receiving input from stakeholders.

Following a round of introductions and background on the project and roles, project partners described the broad themes that were discovered throughout the stakeholder engagement process. Following the presentation, the project partners allowed participants to include additional priorities they wanted to see addressed, and then the project partners conducted an interactive ranking activity. The activity involved asking all participants to rank their top three priorities for both technological priorities and plan takeaway priorities. The ranking system was dictated by colored stickers, red being first, yellow being second, and blue being third.

Technological priorities included off-road equipment, power generation, trucks, ships, light-duty vehicles, materials, and trains; plan takeaway priorities included relevant commitments to zero emission goals, green jobs, education and training, greenspace, public health, coordinating with regional agencies, and climate.

Results:

The project partners found that for technological priorities trucks were a major focal point followed by power generation. And for plan takeaway priorities, public health was clearly top of mind for all participants.

Additional priorities and questions that participants want to see addressed in the blueprint:

- Want the port to prioritize an equitable transition, not simply an equal transition.
- How are other cities, not just Port Hueneme, reacting to the plan?
- Concerned about timelines – needs to be completed quickly.
- How is rail being prioritized within the port? Does the port own the rail line?
- What financing mechanism, like a container fee, can be utilized for the community?
- Focusing on how this will impact environmental justice communities. Is a zero emission corridor a possibility?
- The role other companies, those who are not transitioning to zero emission, have in using the port.
- Community benefit agreements
- Port Hueneme not being in any community choice energy programs (i.e., Clean Power Alliance).
- Is Port Hueneme facilitating any oil import or export?
- The economic externalities to a zero emission port. Will prices rise on goods in the surrounding community?
- How is zero emission defined? Does it mean full electrification or does it include natural gas or hydrogen?
- What is the role Port Hueneme has in wind energy generation and facilitation?

- Concerns surrounding zero emission technologies not being ready for deployment.
- Wanting access to raw data from the SPARC project.

Next Steps:

Some organizations have a strong desire to see the port move to zero emission. These groups have expressed desires to help where possible, particularly when they see tangible steps taken and strong commitments made toward that goal.

Given this, with the caveat that funding is always needed, the project partners recommend creating a working group to address specific technical needs and opportunities. When funding becomes available, the project partners recommend inviting the individuals who attended and actively participated in the working group meetings.

Community Outreach

CCA and BSC are subcontractors on the SPARC project with the goal of providing information to the community on the results of the SPARC project. BSC and CCA distilled the complex technical information presented in the *SPARC Blueprint* to create graphic explanatory documents that were provided in both English and Spanish to the stakeholders who had previously participated in earlier stages of the project and made available online. The audience and focus for the communication materials was informed by the extensive research conducted in the stakeholder engagement phase of the project, also conducted by CCA and BSC. This audience of nearly 200 included community members such as environmental organizations, public health organizations, government agencies, elected officials, business organizations, and labor representatives.

Outreach Strategy:

1. Target audience: The project partners identified key demographics within the potentially affected community, including age, language spoken, and socio-economic factors. An outreach list of 187 members was created during the stakeholder engagement phase.
2. Channel selection: A pamphlet was distributed to stakeholders who had participated in earlier project stages, keeping them informed and engaged. Additionally, the pamphlet was made available online, widening its reach to the broader community.
3. Multilingual approach: All communications and materials were made available in both English and Spanish.
4. Messaging: The messaging focused on educating the community about the planning efforts, potential benefits and impacts, and the future of the port's zero emission efforts. The goal was to bridge the gap between the technical information and detailed plans presented in the *SPARC Blueprint*, distilling its essence into a digestible and engaging format. The project partners emphasized transparency, clear information, and a conversational tone to make the information as accessible as possible to the widest audience. Complex terms were simplified, data was presented visually, and language was kept clear and concise.

Results:

By presenting complex information in a user-friendly format, the community is empowered to participate meaningfully in the SPARC project's discussions and future implementation. This

transparency fosters trust and collaboration, crucial for achieving a successful zero emissions future for the Port of Hueneme. It will allow the port to continue to leverage the engagement and expertise of local stakeholders in the future. Materials were created and distributed to summarize key takeaways to stakeholders and will continue to be made available by port staff in ongoing outreach and engagement efforts.

CHAPTER 4:

Medium-Duty and Heavy-Duty Infrastructure Plan

Infrastructure Planning Parameters:

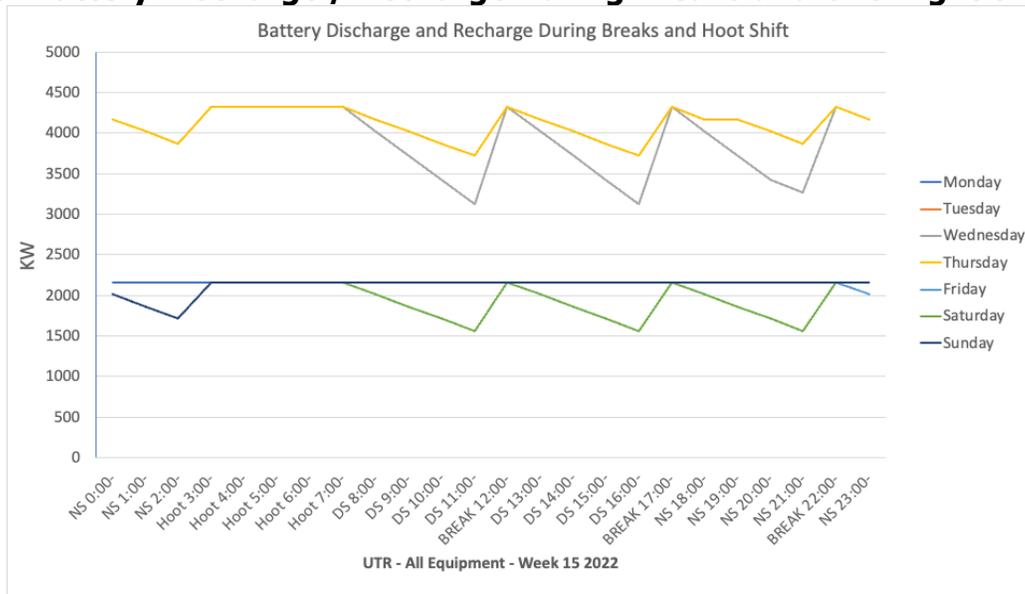
Remaining in line with the 2019 Port of Hueneme electrical master plan, continued deployment of battery-electric CHE has been recommended. An extensive data collection and analysis effort to understand the specific utilization of CHE at the Port of Hueneme was conducted and resulted in the Port of Hueneme Utilization Model. Meeting with port staff, partners, and electrical consultants, CHE utilization was mapped to vessel calls, and a determination of peak electrical loads, if all equipment was to be electrified, was calculated at up to 4 MW for CHE, and 2 MW for shore power. Port of Hueneme electrical consultants recommended that Southern California Edison (SCE) increase circuit capacity to handle the additional load. Infrastructure is to be deployed and owned by the port, requiring careful site selection to support use by multiple operators in the same terminal environment.

Load and Energy Modeling:

The charging infrastructure used for all estimated loads was a 50 kW direct current charger with the capacity to charge two units at 50 kW. Based on the findings in Task 2, there are 36 pieces of CHE that will need charging infrastructure. In a deployment configuration of two charging ports per charger, requiring 18 chargers. Higher charge rates were assessed and should be integrated to support a faster rate of opportunity charging as desired by the operators. Several higher capacity chargers up to 250 kW may be preferred for equipment such as Reach Stackers with larger on-board energy storage.

The battery sizes for each type of CHE were selected based on an analysis of OEM specifications and pilot projects. The chosen sizes—UTRs with 180 kWh, reach stackers with 985 kWh, Class IV forklift with 40 kWh, and Class V forklift with 245 kWh—correspond to the average or median values in the market. Importantly, these sizes were also aligned with the equipment's consumption rates to fit within the available charging windows, in accordance with existing safety and operational protocols. Figure 5 demonstrates the state of charge of proposed equipment over time, based on certain assumed charging windows.

Figure 5: Battery Discharge / Recharge During Breaks and Overnight Shift Chart



Source: *Zero Emission Advisors*

Proposed Infrastructure Sites

The following sites were assessed for viability for siting EV charging infrastructure. Sites have not been finalized for full commercial-scale deployment however, a clear pathway for doing so has been established. There are several planned infrastructure projects funded by the California Department of Transportation Port Freight and Infrastructure Program⁶ that will result in the demolition of buildings to increase usable space for cargo operations. Site evaluation criteria are as follows:

- Impact on current and future operations
- Stranded asset risk
- Proximity to work locations
- Available footprint and site scalability
- Access to electrical service

Satellite images of the Port of Hueneme have been provided for reference (Figure 6). Operations are principally split between the north and south terminals. The north terminal supports rolling stock like automotive imports as well as certain high-and-heavy cargo requiring special support. The south terminal supports container and bulk cargo operations. Space is highly limited despite the port's quick movement of cargo and low dwell times for containers due to the relatively small footprint of the commercial seaport relative to its cargo volumes. Waterfront property is crucial for operations and thus not viable for charging infrastructure, necessitating sites somewhat removed from the berths.

⁶ [California Department of Transportation Port Freight and Infrastructure Program website](https://dot.ca.gov/programs/local-assistance/fed-and-state-programs/port-and-freight-infrastructure-program) (https://dot.ca.gov/programs/local-assistance/fed-and-state-programs/port-and-freight-infrastructure-program)

Figure 6: Port of Hueneme



Source: *Google Earth and Zero Emission Advisors*

CHAPTER 5:

Quantitative Goals and Timelines

Timeline and Key Phases

SPARC technology blueprint (2021-2023): Identifies and outlines a strategic plan of action based on the port's operational requirements and state of technology. In the case of the Port of Hueneme, the *SPARC Blueprint* was created to chart a pathway to zero emission CHE operations which is the port's overall long-term plan for air quality improvement and climate change adaptation. The plan takes a comprehensive look at the operations of MDHD equipment to address technology selection, and infrastructure requirements, and plot a timeline for the complete transition of equipment to zero emission alternatives.

Formally engage SCE regarding electrical service requirements (2023-2025): The port does not currently have sufficient capacity to support CHE electrification goals. It is imperative that the port formally engage SCE and submit an electrical service request to prepare to meet electrification goals. The port can leverage the existing electrical master plan along with newly forecasted loads from the *SPARC Blueprint* to support SCE's understanding of the required electrical for future facility expansions and equipment electrification projects. The electrical master plan lists the existing major electrical loads currently installed at the Port of Hueneme's south and north terminals and can be updated as appropriate to incorporate projected new electrical loads.

Policy development and implementation (2023-2025): Central to enabling a forecastable and timely transition to zero emission operations will be implementing several port policy changes. It is recommended that the port set clear guidelines on how infrastructure is developed, owned, and operated to create a consistent and unified approach to infrastructure deployment. Limitations on when and how new fossil fuel equipment can be integrated into the port ecosystem will need to be set to ensure compliance with the port's zero emission targets. The port can leverage tariff agreements, board resolutions, and lease agreements to collaboratively affect these changes with its commercial partners. The port can also implement incentives for commercial partners to adopt zero-emission CHE in support of infrastructure deployment. The port will be undergoing the development of a comprehensive clean air action plan, which will address the policy gaps necessary to support a holistic energy transition.

Fleet transition (2025-2030): Activate commercial-scale deployment of zero emission infrastructure and CHE with port partners within the revised policy framework and electrification goals (Table 3). Integrate any engineering and design considerations from climate change adaptation work regarding stormwater intrusion and sea level rise for critical infrastructure. This will also allow time to complete necessary engineering and design work for the deployment of additional EV charging infrastructure and prepare for procurement. The port taking the lead on infrastructure development will reduce stranded asset risk and operational risk associated with user-driven one-off deployments. The port should consider both public and private sources of funding to support operator equipment adoption and port infrastructure deployments.

Table 3: Proposed Fleet Transition Timeline

Year	Diesel UTR	EV UTR	Diesel Forklift Class V	EV Forklift Class V	Diesel Harbor Crane	Hybrid Harbor Crane	Diesel Reach Stacker	EV Reach Stacker
2023	25	2	3	0	2	1	3	0
2024	16	11	3	0	1	2	3	0
2025	16	11	3	0	0	3	3	0
2026	11	16	3	0	0	3	3	0
2027	6	21	3	0	0	3	3	0
2028	2	25	2	1	0	3	2	1
2029	0	27	1	2	0	3	1	2
2030	0	27	0	3	0	3	0	3

Source: *Zero Emission Advisors*

Parallel decarbonization projects to support zero-emission port operations (2023-2036): Additional projects will remove dilapidated, obsolete buildings, install zero-emission container plug-in units, and have some limited on-site generation capacity. Said projects will bring resilience and safety improvements while paving the way for new zero emission infrastructure. Continued support of shoreside power and emission control systems that ensure compliance with CARB at berth regulations will ensure emissions reductions of ocean-going vessels while in port. Growing EV imports also raise the issue of potential charging needs for imported vehicles along with the potential for more efficient use of port space through the development of a parking garage.

Foster Innovation and Regional Partnerships (Ongoing): Foster an environment of innovation, encouraging new technologies and solutions. Form partnerships with stakeholders, including local communities, businesses, research institutions, and government agencies. Leverage convening authority and potential as a project partner to enable regional projects that improve the resilience of local infrastructure and supply chains, promote economic development and reduce air pollution.

100 percent of all UTRs will be EVs by 2030, which is an estimated five units per year starting in 2026. That year was chosen to allow for 18 months to 24 months to select, permit, and install electrical infrastructure. This timeline can be accelerated based on available funding opportunities and operating willingness to adopt on a more aggressive timeline.

Consideration of Hydrogen Technology

In the comprehensive assessment of potential solutions for zero-emission CHE at the Port of Hueneme, the project partners considered various energy alternatives, including hydrogen. The decision to not recommend hydrogen at this stage is based on the following considerations:

- **TRL Status:**

- Hydrogen technology's TRL 7 status signifies that it has been demonstrated in an operational environment but still requires further development to reach full commercialization.
- In contrast, battery electric technology has reached TRL 9, indicating that it's well established and tested in multiple operational environments. This difference in maturity levels contributes to the current preference for battery electric solutions.
- The project partners recognize the future potential of hydrogen, especially for heavy-duty applications (container handlers and harbor craft), and will continue to monitor its progression. Any significant advancements in technology readiness could prompt a reevaluation of its applicability.

- **Port of Hueneme's Operational Context:**

- Unlike larger container ports, the Port of Hueneme has a different operational tempo and duty cycle reducing the endurance requirements of its equipment. This is largely due to the size of the vessels that make calls at the port based on the wharf infrastructure; this constrains the overall container volume per vessel.
- The reduced duty cycle allows for less frequent battery discharging and provides shorter charging cycles. This supports optimal battery health by maintaining charge levels between 20 percent and 80 percent.
- The Port of Hueneme utilization model demonstrated that most CHE did not drop below 70 percent battery charge before a charging window was available.

- **Infrastructure and Cost Challenges:**

- Hydrogen would necessitate substantial investment in refueling infrastructure, with estimated costs far greater than EV charging alternatives. The current hydrogen supply is limited, though rapidly expanding. Time will be needed before cost parity with diesel.
- The existing electrical infrastructure can be expanded and provide a lower cost of energy for equipment operation.
- Other energy alternatives such as biofuels and synthetic fuels were also considered but did not align with the State of California's policy goals and posed a greater risk of stranded assets.

Estimated Environmental Impacts

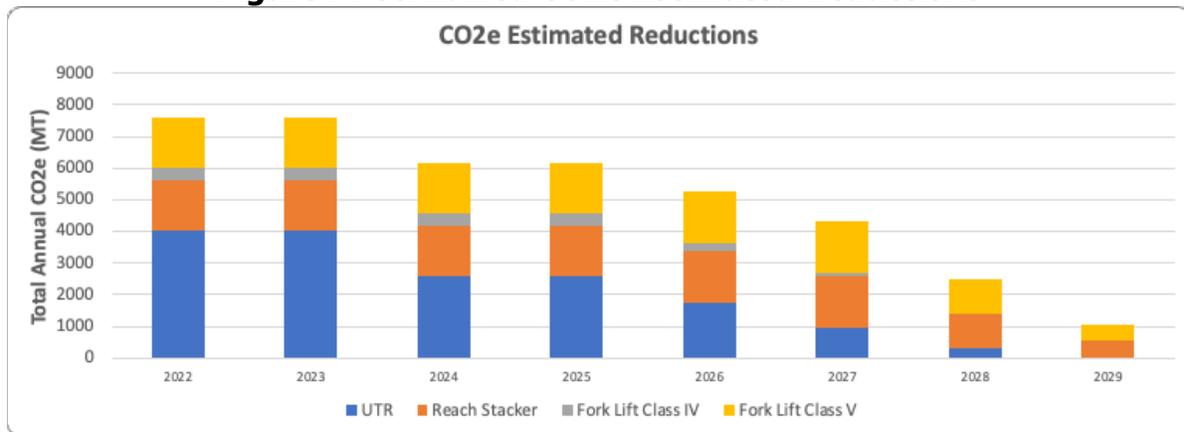
The surrounding communities range from the 40th percentile to 80th percentile under CalEnviroScreen 4.0.⁷ Specifically, the census tract directly east of the port represents several disadvantaged communities with a population characteristics in the 69th percentile and a pollution burden in the 83rd percentile. The port has invested heavily over the years to monitor local air quality and reduce air pollutants related to port operations. The *SPARC*

⁷ [CalEnviroScreen 4.0 website](https://oehha.ca.gov/calenviroscreen) (https://oehha.ca.gov/calenviroscreen)

Blueprint is another step in this ongoing effort and has mapped a transition of all CHE which would provide notable air quality benefits to this population and others in the air basin. While the port is not the sole nor largest contributor to air pollutants, exhibiting strong leadership and leveraging its convening authority within the local logistics community will enable significant progress toward improving public health and air quality for the county.

The proposed plan will also contribute to CARB’s 2030 zero emission and near-zero emission regulation by affecting the transition to zero-emission CHE to significantly reduce greenhouse gas emissions and criteria air pollutants (Figure 7).

Figure 7: Combined CO2e Estimated Reductions



Source: *Zero Emission Advisors*

GLOSSARY

BREATHE SOUTHERN CALIFORNIA (BSC)—A non-profit community organization that promote clean air and healthy lungs through research, education, advocacy and technology.⁸

ELECTRIC VEHICLE (EV)—EVs utilize energy that is stored in rechargeable battery packs. EVs sustain their power through the batteries and therefore must be plugged into an external electricity source in order to recharge.

CALIFORNIA ENERGY COMMISSION (CEC)—The state agency established by the Warren-Alquist State Energy Resources Conservation and Development Act in 1974 (Public Resources Code, Sections 25000 et seq.) responsible for energy policy. The Energy Commission's five major areas of responsibilities are:

1. Forecasting future statewide energy needs.
2. Licensing power plants sufficient to meet those needs.
3. Promoting energy conservation and efficiency measures.
4. Developing renewable and alternative energy resources, including providing assistance to develop clean transportation fuels.
5. Planning for and directing state response to energy emergencies.

CARBON DIOXIDE EQUIVALENT (CO₂e)—A metric measure used to compare the emissions from various greenhouse gases based upon their global warming potential.

CARGO HANDLING EQUIPMENT (CHE)—Any motorized vehicle used to handle cargo or perform routine maintenance activities at ports, freight distribution centers, and intermodal rail yards. The type of equipment includes yard trucks, rubber-tired gantry cranes, container handlers, forklifts, etc.⁹

COALITION FOR CLEAN AIR (CCA)—An organization that works with advocates, organizations, companies, legislators and more across the state to find cooperative solutions to California's air quality issues in order to improve air quality and improve public health.¹⁰

COMMERCIAL READINESS LEVEL (CRL)—A measure on a scale of 1 to 9 of how ready a technology is to be made commercially available, starting from the belief a new technology could be commercially successful all the way through to full regulatory compliance, commercial availability and wider acceptance within the target market.¹¹

⁸ [Breathe Southern California website](https://www.breathesocal.org/) (https://www.breathesocal.org/)

⁹ [California Air Resources Board](https://ww2.arb.ca.gov/our-work/programs/cargo-handling-equipment) (https://ww2.arb.ca.gov/our-work/programs/cargo-handling-equipment)

¹⁰ [Coalition for Clean Air website](https://www.ccair.org/) (https://www.ccair.org/)

¹¹ [British Institute of Non-Destructive Testing website](https://www.bindt.org/What-is-NDT/Index-of-acronyms/C/crl/) (https://www.bindt.org/What-is-NDT/Index-of-acronyms/C/crl/)

ENVIRONMENTAL MANAGEMENT FRAMEWORK (EMF)—A set of work plans intended to provide a roadmap for the implementation of projects by proactively pursuing projects and programs aimed at pollution prevention and natural resource protection.¹²

FUEL CELL ELECTRIC VEHICLE (FCEV)—A zero-emission vehicle that runs on hydrogen fed into a fuel cell that produces electricity to power the vehicle.

GREENHOUSE GAS (GHG)—Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include water vapor, carbon dioxide, methane, oxides of nitrogen, halogenated fluorocarbons, ozone, perfluorinated carbons, and hydrofluorocarbons.

GROSS DOMESTIC PRODUCT (GDP)—The total market value of the goods and services produced by a nation before deduction or depreciation charges and other allowance for capital consumption and is widely used as a measure of economic activity.

INTERNATIONAL ENERGY AGENCY (IEA)—An autonomous intergovernmental organization, established in 1974, that provides policy recommendations, analysis and data on the global energy sector.¹³

KILOWATT (kW)—A unit of energy measurement equal to 1,000 watts. A watt is equal to one ampere under a pressure of one volt.

KILOWATT-HOUR (kWh)—The unit of measure telling the amount of kilowatts consumed over the course of one hour.

MEDIUM- AND HEAVY-DUTY (MDHD) - Vehicles that have a gross vehicle weight rating of more than 10,000 pounds and includes vans, buses, trucks, and off-road cargo handling equipment.

MEGAWATT (MW)—A unit of energy measurement equal to one million watts. A watt is equal to one ampere under a pressure of one volt.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)—An independent agency of the U.S. federal government responsible for the civil space program, aeronautics research, and space research.¹⁴

NITROGEN OXIDES (OXIDES OF NITROGEN, NO_x)—A general term pertaining to compounds of nitric oxide (NO), nitrogen dioxide (NO₂), and other oxides of nitrogen. Nitrogen oxides are typically created during combustion processes and are major contributors to smog formation and acid deposition. NO₂ is a criteria air pollutant and may result in numerous adverse health effects.

ORIGINAL EQUIPMENT MANUFACTURER (OEM)—A company that provides the original design and materials for manufacture and engages in the assembly of vehicles. The OEM is directly responsible for manufacturing, marketing, and providing warranties for the finished product.

¹² [E2 ManageTech staff. 2013. *Environmental Management Framework: Strategic Implementation Plans*. Oxnard Harbor District – The Port of Hueneme. E2 Project Number: 12-144-002.](https://www.portofhueneme.org/wp-content/uploads/2014/06/POH_E2_Framework_2015.pdf) (https://www.portofhueneme.org/wp-content/uploads/2014/06/POH_E2_Framework_2015.pdf)

¹³ [International Energy Agency website](https://www.iea.org/) (https://www.iea.org/)

¹⁴ [National Aeronautics and Space Administration website](https://www.nasa.gov/) (https://www.nasa.gov/)

SULFUR OXIDES (OXIDES OF SULFUR, SO_x)—Pungent, colorless gases (sulfates are solids) formed primarily by the combustion of sulfur-containing fossil fuels, especially coal and oil. Considered major air pollutants, sulfur oxides may impact human health and damage vegetation.

PARTICULATE MATTER 10 (PM₁₀)—Unburned fuel particles small than 10 microns in diameter that form smoke or soot and stick to lung tissue when inhaled. It is a chief component of exhaust emissions from heavy-duty diesel engines.

PORT OF HUENEME—The Port of Hueneme in the city of Port Hueneme, California, United States, is the only deep water harbor between Los Angeles and the San Francisco Bay area.¹⁵

STATE IMPLEMENTATION PLANS (SIP)—A collection of regulations and documents used by a state, territory, or local air district to implement, maintain, and enforce the National Ambient Air Quality Standards, or NAAQS, and to fulfill other requirements of the Clean Air Act.¹⁶

SOUTHERN CALIFORNIA EDISON COMPANY (SCE)—An electric utility serving the southern California region.

SUSTAINABLE POWER ADVANCEMENT AND RESILIENCY FOR OUR COMMUNITY (SPARC) – a planning document created to chart a pathway to zero emission port operations for the Port of Hueneme’s overall long-term plan for air quality improvement and climate change adaptation.¹⁷

TECHNOLOGY READINESS LEVEL (TRL)—A type of measurement system used to assess the maturity level of a particular technology. Each technology project is evaluated against the parameters for each technology level and is then assigned a TRL rating based on the projects progress. There are nine technology readiness levels. TRL 1 is the lowest and TRL 9 is the highest.¹⁸

UTILITY TRACTOR RIG (UTR)—A type of heavy-duty vehicle intended to move semi-trailers within a cargo yard, warehouse facility, or intermodal facility. Also known as a terminal tractor or a yard tractor.¹⁹

¹⁵ [Port of Hueneme website](https://www.portofhueneme.org/) (https://www.portofhueneme.org/)

¹⁶ [United States Environmental Protection Agency Air Quality Implementation Plans website](https://www.epa.gov/air-quality-implementation-plans/about-air-quality-implementation-plans#:~:text=A%20State%20Implementation%20Plan%20(SIP)%20is%20a%20collection%20of%20regulations,of%20the%20Clean%20Air%20Act.) (https://www.epa.gov/air-quality-implementation-plans/about-air-quality-implementation-plans#:~:text=A%20State%20Implementation%20Plan%20(SIP)%20is%20a%20collection%20of%20regulations,of%20the%20Clean%20Air%20Act.)

¹⁷ [The SPARC Blueprint Project website](https://www.ccair.org/clear/the-blueprint-sparc-project/) (https://www.ccair.org/clear/the-blueprint-sparc-project/)

¹⁸ [National Aeronautics and Space Administration website](https://www.nasa.gov/directorates/somd/space-communications-navigation-program/technology-readiness-levels/) (https://www.nasa.gov/directorates/somd/space-communications-navigation-program/technology-readiness-levels/)

¹⁹ [Utility Tractor Rig definition website](https://en.wikipedia.org/wiki/Terminal_tractor) (https://en.wikipedia.org/wiki/Terminal_tractor)