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Marine Decarbonization & ESG White Paper
Market Drivers, Challenges and AECOM Capabilities & Opportunities

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Introduction

Many of the Port development projects performed by AECOM over the last several decades have included elements of marine decarbonization and/or ESG, whether as focused projects or embedded within infrastructure development. These have ranged from addressing port-wide environmental and community concerns to implementation of sustainability, resilience and reliability measures into projects and, perhaps of paramount importance, reduction of diesel-related and greenhouse gas emissions.

Marine decarbonization project have comprised implementation of measures, construction of infrastructure and facilities, and installation of equipment to reduce carbon footprints and emissions within the maritime sector. The focus of these efforts has been the primary sources of air pollution associated with the ports and marine sector, which ranges from mobile and fixed sources within port complexes to the many types of vehicles that access ports (particularly trucks) and the ships and other equipment being operated by global shipping and cruise lines. The AECOM Ports & Marine (P&M) Practice is at the forefront of marine decarbonization with over 20 years of relevant project experience.

Air Pollution in Ports

Emissions of concern are diesel-related (diesel particulate matter [DPM], nitrogen oxides [NOx], sulfur oxides [SOx], carbon monoxide [CO], and hydrocarbons [HC]) and greenhouse gases (GHG or carbon dioxide equivalent [eCO_2]). Many studies have documented the lower life expectancies (by as much as 10 to 15 years) in communities surrounding ports, which also tend to be lower socioeconomic communities. Air pollution associated with port facilities and operations, and implementation of decarbonization programs, is the primary issue currently being addressed within the maritime industry as various stakeholders (Port Authorities, municipal agencies, terminal operators, cargo lines, cruise lines, Port tenants, Port customers, and regulatory authorities) tackle a myriad of global, federal, state, and local regulatory, political and community challenges.

Addressing emissions from vessels, which are the largest mobile sources of air pollution affecting Ports and their surrounding communities, is at the forefront of any decarbonization/ESG/climate action program. These programs are driving electrification of port facilities and marine terminals, alternative fuel and/or renewable power solutions, and conversion of terminal (cargo handling) equipment, non-terminal equipment (trucks and locomotives), and small vessels (tugs, barges, ferries, and dredgers) to electrification or alternative fuels.


Typical Port Emissions

Currently, electrification of equipment (battery-electric) is the primary approach as this solution is the most advanced and more readily available technology. However, various alternative (future) fuels are being assessed and/or implemented, such as hydrogen (and ammonia) fuel cells, e-methanol, biodiesel, and other lower emissions fossil fuels (e.g.- LNG), which range from overall emissions reductions to achieving near-zero or net-zero emissions. These future fuel alternatives appear to offer the most benefit, however, significant advances and improvements in the technologies, supply, storage and delivery are required for these to be cost-effective widely utilized solutions.

Market Drivers

In U.S. Ports, marine decarbonization ranges from a high level of maturity to practically non-existent. The major U.S. West Coast ports are all addressing marine decarbonization programs, to varying degrees, to comply with regulatory requirements and governmental policies/programs. In California, some decarbonization measures are mandatory and well-established (such as shore-to-ship power) and State requirements are driving implementation of robust port-wide decarbonization programs to meet zero-emissions goals. In fact, port development projects are not approved and permitted unless they implement appropriate design, construction and mitigation measures to meet regulatory requirements and satisfy governmental, agency and community concerns. The Ports of Los Angeles and Long Beach are at the forefront of implementation and have become incubators and test beds for pilot scale testing of new technologies, alternative fuels and equipment focused on reducing and/or eliminating emissions.


Port of Los Angeles

U.S. Ports are generally not being driven by governmental agencies or regulations and many ports are not currently addressing marine decarbonization. Some of the reasons for this are concerns about costs and inability to fund these types of projects, perceived limitation of space to support related facilities and infrastructure, and lack of understanding/knowledge. However, there is increasing recognition that emissions reductions programs are becoming necessary, particularly as Port customers and tenants (such as global terminal operating companies and shipping/cruise lines) strive to comply with global emissions policies and standards, a well as their own ESG policies/programs. An example is the International Maritime Organization (IMO) 2023 regulation to reduce carbon emissions from international shipping by 40% by 2030 and 70% by 2050 versus the 2008 levels.

Market drivers for implementation of marine decarbonization/ESG programs include:

- Global shipping regulations,
- National/regional regulatory mandates,
- Industry ESG (or equivalent) Programs implemented by Ports, terminal operators and shipping/cruise lines,
- Investors in shipping/cruise lines requiring ESG programs (such as Blackstone and Blackrock),
- Public agency funding programs, such as IIJA and IRA in the U.S. and EU funding in Europe,
- Costs of diesel fuel,
- Advancements in development of alternative fuels, such as hydrogen for upland equipment and LNG and methanol for vessels, and
- Third-party entities that are buildings/financing decarbonization solutions for industry.

Industry Challenges

There are several significant challenges currently impacting conversion from diesel equipment and implementation of marine decarbonization measures. These include:

- Availability of battery-electric equipment is impacted by the global supply and availability of key resources for manufacture (such as rare earth metals).
- Local power grids quite often do not have capacity and/or are not reliable to support port electrification programs (many ports already face this issue today).
- Future-fueled equipment (hydrogen, ammonia) are still in the early stages for development and not readily available or cannot yet support some of the decarbonization needs.
- Availability of future fuels are limited, with very few supply and delivery solutions located near U.S. Ports.
- Future fuels are generally not yet zero-emissions solutions, which eliminates them as a solution in select locations (such as California which has mandates for zero-emissions equipment).
- Significant investment is necessary to support production of zero-emissions future fuels (e.g., solar power is necessary to produce green hydrogen) and space is not readily available.
- Alternative equipment solutions are more costly than diesel-fueled equipment (about 2-3x for battery-electric and as much as 4-6x for future fuels).
- Electrification of marine terminals, particularly container terminals, require significant investment for the necessary cargo handling equipment.
- Implementation of port-wide decarbonization require collaboration from all stakeholders to address all equipment utilized within port complexes, including ports, terminal operators, shipping/cruise lines, rail operators, truckers, and labor unions)
- Funding solutions (such as federal grants) do not cover the full costs required for “green” conversion of equipment and/or power sources and many Ports and terminal operators do not have budget availability to support conversion.


Port of Houston

AECOM Capabilities

For the AECOM P&M Practice, almost all of our clients are addressing decarbonization/ESG to varying degrees. Some of the projects being performed are decarbonization focused (such as a berth shore-to-ship power retrofit project or electrification of terminal equipment) and most, if not all, capital development projects are addressing decarbonization/ESG in one form or another (such as a container terminal electrification program). The type of marine decarbonization and ESG work being performed by AECOM is summarized below.

Decarbonization

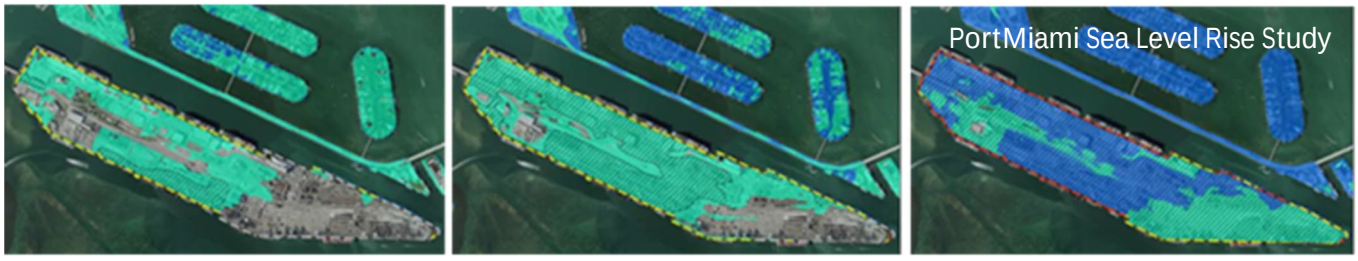
- Emissions inventories and air quality studies
- Energy efficiency, alternative fuel, alternative power, and electrification studies
- Planning, engineering, design, and program/construction management for projects that are focused on or include:

- Shore-to-ship power systems,
- Shore-to-ship crane electrification,
- Container yard and intermodal yard electrification,
- Container terminal automation,
- Hybrid and electric terminal equipment,
- Hybrid and electric non-terminal equipment (trucks, locomotives),
- Charging and alternative fueling stations,
- Vessel carbon capture systems,
- Small vessel electrification (hybrid, full electric or alternative fuel), including tugs, ferries, barges, and dredges,
- On- and off-terminal alternative power solutions, including solar arrays, battery storage systems, wind turbines, fuel cells, and LNG/natural/gas power parges.
- Production, storage and delivery of alternative fuels (eg. hydrogen, ammonia, LNG, methanol, etc.), and
- Offshore wind marine terminals.


Louisiana International Terminal Concept, Port of New Orleans

ESG

- Port master planning that also address resiliency, decarbonization, sustainability, etc.,
- Development of sustainability management plans.
- Climate change and sea level rise vulnerability assessments.
- Shoreline, flooding, and sea level rise protection systems.
- Building energy efficient systems.
- Sustainable design measures and materials.
- LEED and Envision design and certification.
- Beneficial reuse of dredged and construction materials.
- Addressing contaminated (soil, groundwater, hazardous) materials.
- Habitat restoration and creation of aquatic habits.
- Protection and/or relocation of sensitive species (sea grass, coral, etc.).
- Marine species monitoring and implementation of protection measures.
- Construction emissions, dust, noise, vibration, and stormwater discharge mitigation measures.



AECOM has the full range of capabilities to provide the above services and the pertinent expertise and experience is available in all of AECOM's business lines. The P&M Practice regularly taps into the other BLs and various practice groups to obtain the necessary resources to provide some of these services.

Relevant Project Experience

AECOM P&M has extensive marine decarbonization and ESG related project experience over the last two decades. These range from projects focused on decarbonization/ESG to developments with embedded decarbonization/ESG elements. In general, all major marine terminal development projects performed by AECOM have include decarbonization/ESG. A summary of relevant projects is presented in Attachment A. These projects include:

- Port-wide decarbonization,
- Terminal decarbonization/electrification,
- Terminal equipment decarbonization,
- Vessel decarbonization
- Shore-to-ship power systems,
- Alternative/renewable power,
- Terminal building sustainability,
- Offshore wind terminals,
- Alternative transportation systems, and
- Climate change/sea level rise vulnerability assessments.


Port of Salem Wind Marshalling Terminal Concept

Potential Projects

Many of AECOM's current major global maritime clients have established ESG programs that include emissions reductions goals or are engaged in developing, implementing and financing projects that support decarbonization programs. In addition, within the U.S., most Ports are evaluating the level of decarbonization to implement into infrastructure, facilities and equipment. Potential marine decarbonization projects that are likely to be performed in the near future are summarized below.

- Upgrade and retrofit of waterfront facilities for shore-to-ship power and/or vessel carbon capture systems, which includes: petroleum and RORO terminals in California (now mandated, cruise lines continuing to pursue shore power worldwide (to comply with IMO2023), and ports providing shore power for container terminals (for shipping lines compliance with IMO2023)
- Electrification of marine terminals, especially in California to meet zero-emissions State goals, as well as general reduction of emissions throughout the U.S., which includes electrified and/or automate cargo handling equipment and required supporting infrastructure.
- Electrification of small vessels, and shoreside charging systems, to address Scope 1 emissions reductions goals. Examples include ferry systems and tug operators (e.g., Crowley).
- Alternative fuels for terminal equipment, as an alternative to battery-electric, such as hydrogen/ammonia fuel cells, LNG and future fuels.
- Alternative and/or renewable power solutions (off-grid and/or behind-the-meter) for ports and terminals to meet increasing power demands with port electrification projects, particularly where power grids don't have capacity, are already unreliable or need increased resilience.


Cruise Shore-to-Ship Power

- Facilities to support production, storage and delivery of future fuels (methanol, LNG, hydrogen, biodiesel, etc.) that will require significant increase in volumes to support shipping/cruise line and terminal operator goals to reduce reliance on diesel fuel.
- Wind fabrication, marshalling, and O&M terminals along the U.S. West and Gulf coasts to support offshore wind development to meet significant federal goals for wind power.
- Marine decarbonization related development in the Caribbean Basin and South America, which includes each of the above-mentioned opportunities.


Port of Long Beach
H2 Trigeneration Facility

The maritime clients from which there will be decarbonization/ESG projects are summarized below.

- Port Authorities – Examples include Ports of Los Angeles, Long Beach, New Orleans, and Miami.
- International governmental agencies or departments – Examples include Caribbean Basin countries that are evaluating alternative/green power sources and port-wide shore power systems and European Union countries that are implementing shore power programs.
- Global and national terminal operators, such as APM Terminals, DP World, Ports America, and SSA Marine.
- Shipping lines, such as Maersk, CMA CGM, MSC, etc.
- Cruise lines, such as Royal Caribbean, Carnival, Norwegian, MSC, Disney, etc.
- Oil & Gas companies that are investing in and developing decarbonization projects, as well as renewable power and alternative fuel solutions, such as Shell, Marathon Petroleum, ConocoPhillip, etc.


PortMiami Cruise Terminals

- Third-party developers for decarbonization projects, such as LNG (and other alternative fuel) suppliers and infrastructure or energy investments funds.
- Offshore wind developers.
- Multi-sector entities that address several of the above categories, such as Crowley Marine Services (which builds and operates terminals, cargo vessels, tugs, and bunkering barges).

Summary

There will be significant focus on (and funding for) marine decarbonization (and ESG) in the near future, with most, if not all, of AECOM's current clients implementing decarbonization programs and projects. AECOM has strong capabilities with 20+ years of experience performing these types of projects and we are well positioned to provide these services. We are subject matter experts in some of these areas (such as terminal electrification, shore power, renewable power, and alternative fuels) and provide a wide range of services/disciplines to offer a full suite of solutions (i.e. bundling or menu of options). Our experience validates that we know how to develop and implement infrastructure projects that can achieve decarbonization goals and demonstrate measurable and verifiable progress and success.

Summary of AECOM's Marine Decarbonization Experience

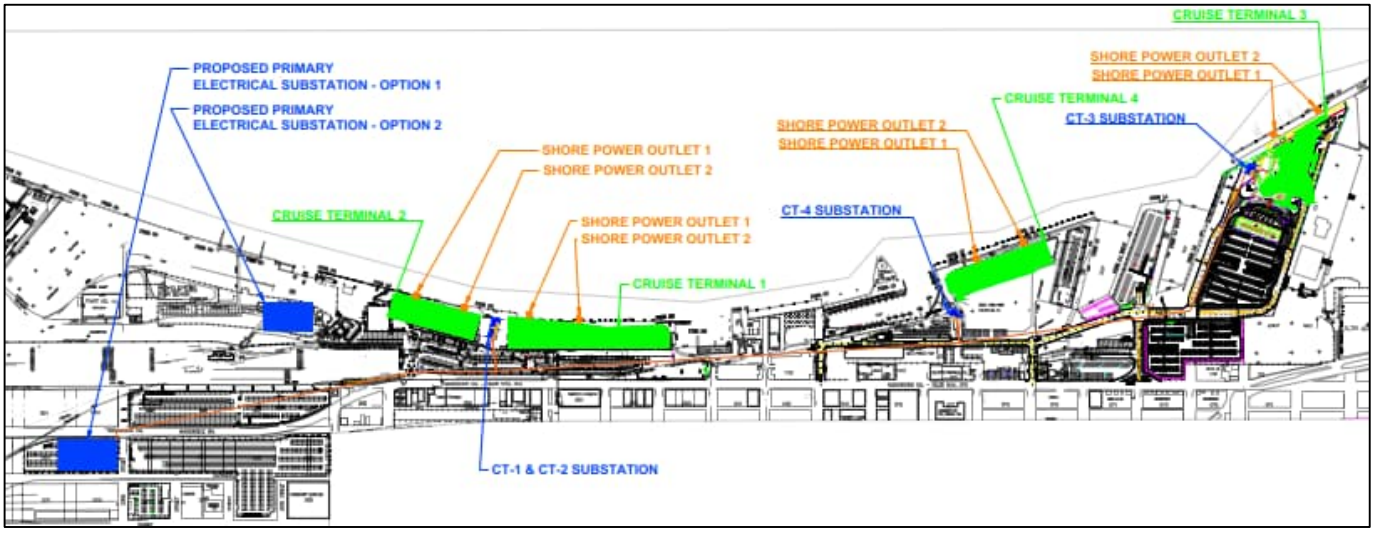
AECOM's marine decarbonization experience has included: electrification of marine terminals and port facilities, shore-to-ship power and carbon capture systems, renewable power and alternative (future) fuel solutions, and near-zero and zero emissions equipment and transportation systems. Services provided by AECOM has ranged from performing emissions testing, analyses and baseline inventories, environmental assessment and permitting to planning, engineering, design, and construction support and commissioning. Some of our marine decarbonization project experience are presented below.

Port-Wide Decarbonization

Port of Galveston Port-Wide Power and Cruise Shore Power Program, Texas



AECOM evaluated the feasibility and developed a conceptual plan and estimated costs to provide shore power for four cruise terminals (three existing and one future) at the Port. AECOM then performed Pre-FEED services for the Port-Wide Power and Cruise Shore Power Program, which includes a new transmission substation, electrical distribution network to four cruise terminals, shore power substations and systems within the terminals, and solar arrays and batteries for alternative power solutions. These services have included preparation of a Concept Selection and Basis for Design Reports, emissions analyses to determine the environmental benefits from reduction of ship emissions pollutants, and development of preliminary design drawings, estimated construction costs, project schedule, and risk register.



PortMiami Port-Wide Shore Power Feasibility Study and Cruise Shore Power Program, Florida

AECOM is PortMiami's Program Management Consultant for implementation of their Capital Development Program. In this role, AECOM services and Program Manager, Construction Manager and/or Owner's Representative for most of the Port's significant development projects, which includes the Port's Shore Power Program.



AECOM developed a concept plan and ROM costs to provide shore power throughout PortMiami for all cruise and cargo berths. This Study was performed in 2020, with AECOM continuing to support the Port with this program providing the following services: coordination with Florida Power & Light for main substation and power supply requirements; technical and cost estimating support for preparation of an EPA DERA grant application for a cruise shore power pilot project; served as Owner's Representative for development of the concept/basis of design and engineering design packages to provide shore power to five cruise berths (Phase 1, Cruise Program); and technical expertise during construction of the Phase 1 Cruise Program. Currently in construction, shore power systems are being installed at cruise terminals for the Carnival, MSC, Norwegian, Royal Caribbean, and Virgin Voyages cruise lines.

Port Canaveral Port-Wide Cruise Shore Power Feasibility Study, Florida





AECOM evaluated the feasibility and developed a concept plan and estimated costs to implement port-wide cruise shore power systems, which included six cruise terminals and berths, with consideration for a future seventh berth. The Study included coordination with Florida Power & Light to determine available capacity in the power grid, transmission system upgrade requirements, new distribution systems to feed the cruise terminals, and shore power systems for each of the cruise berths. The Study included evaluation of the range of cruise ship classes and sizes for five cruise lines (Carnival, Disney, Norwegian, MSC and Royal Caribbean) to determine shore power connection needs on the berth, including requirements for cable management systems. The study determined that 77 MW of additional power is required to support shore power operations.

Terminal Electrification

APMT Pier 400 Container Terminal Modernization & Automation, Port of Los Angeles, California

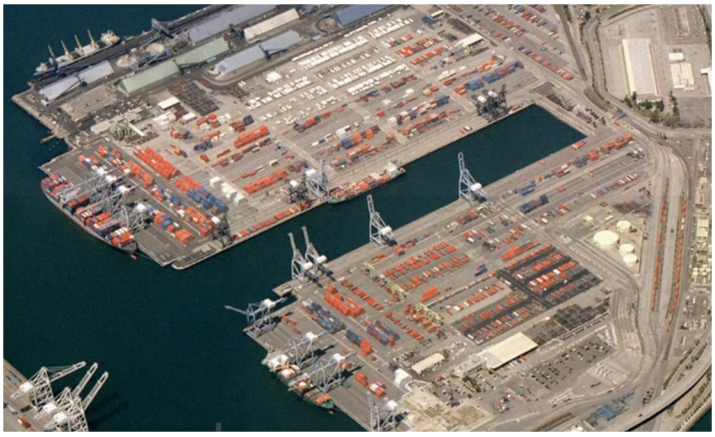
AECOM has been providing PM/CM services for modernization, electrification and automation of the Pier 400 container terminal. The project will create a fully automated container yard operation using straddle carriers from quay cranes to stacking areas to street truck exchange lanes. The program is being constructed in phases to accommodate fast tracking of equipment testing and commissioning, for earliest possible start of commercial operations to capture the economic benefits of automation.



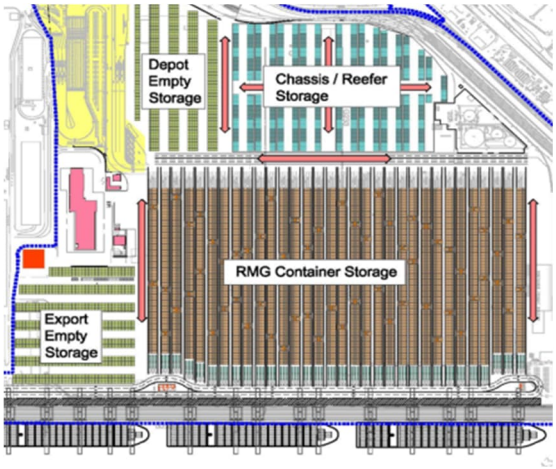
The first phase (completed) encompassed civil/electrical construction, including paving, truck exchange lanes, airlocks for straddle carrier fueling and maintenance, x-ray scanning, US Customs inspection, reefer racks, associated communication and technology installations, and completing electrical distribution networks. The second phase is in progress and involves sequential yard area and truck exchange lanes construction on top of continued manual yard operations and newly opened automated operations to capture the economic benefits of automation. As PM/CM we were also involved with coordinating installations of antennae and guidance system hardware and installations and assuring readiness for operations handover.

Pier G Container Terminal Redevelopment Program, Port of Long Beach, California

From 2009 through 2021, AECOM provided planning, engineering, design, and construction support services for Phases 2-4 of this estimated $1B redevelopment program for expansion, modernization, electrification, and potentially automation of the 300-acre terminal to increase cargo handling productivity and efficiency. The program was to include filling in the middle slip area and creating a single 4,000-foot-long wharf that could handle the next generation of Super-Post-Panamax ships.



Automation studies were performed to evaluate feasibility for implementation, increases in throughput and reduction of emissions. Near-zero and zero-emissions container handling equipment options were evaluated with corresponding projected terminal performance, reliability of productivity, worker's safety, and equipment and operating cost impacts. Automated stacking cranes (ASCs) and automated straddle carriers were selected for terminal operations, with an estimated 3.5M TEU annual throughput, and advanced into planning and design.



The program involved performing multiple projects over a 10-year period, which included: shore power retrofit of two wharves; two slips fills and development for container storage; demolition of terminal buildings; redevelopment of terminal areas; on-dock railyard expansion and main line improvements; two new wharf/berth additions, with shore power; shore power retrofit of two existing berths; secondary gate complex; new transmission service and substations. Projects were performed by AECOM to various stages of completion ranging from construction to detailed (100%) design, for the Phase 2 and 3 projects, and preliminary design for some of the Phase 4 projects. Completion of the program was put on hold pending development and certification of a new EIR to address increased throughput resulting from automated operations.

Hugh K. Leatherman, Sr. Container Terminal Development, North Charleston, South Carolina

AECOM performed planning, engineering, design, and permitting for a new 280-acre greenfield container terminal development along the Cooper River on a former naval facility site that was to utilize electric RTGs to efficiently handle growing containerized cargo volumes and provide electrified operations, while accommodating the increasingly larger container ships being deployed by the ocean carriers. This multi-phase development, when completed, will result in a 3,500-foot-long 3-berth container wharf, dredging and upland disposal of 2.4M cy for channel and berth deepening, and terminal with eRTG container yard, reefer racks, entry/exit gates, and 12 buildings and structures.





The terminal is to be developed in three phases. Phases 1 and 2 were designed to a 100% level and included separate bid packages for: site surcharging and preparation; site access roads and bridges; Phase 1 wharf and berth dredging; administration, maintenance and repair, gate, and terminal buildings and canopies; Phase 1 site/terminal development; Phase 2 wharf and berth dredging; Phase 2 container yard development; and navigation channel and turning basin deepening/widening. Phase 3 was completed to a 30% level and included the 3rd berth and final container yard expansion. Phase 1 was completed and opened for operations in March 2021.

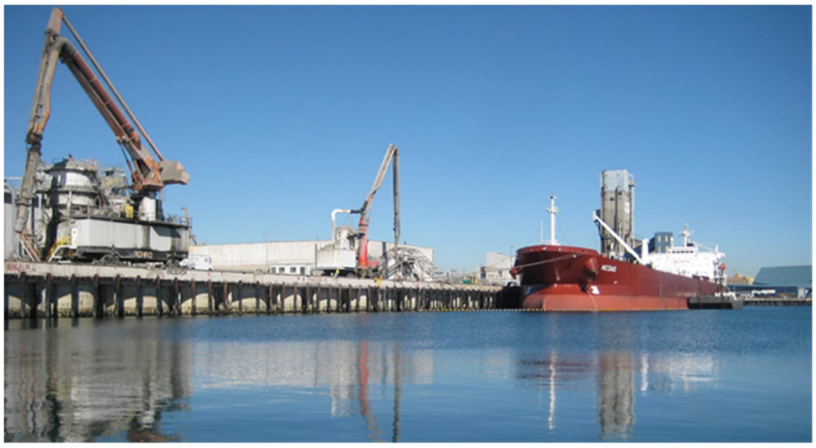
Louisiana International Container Terminal, New Orleans, Louisiana

AECOM performed a siting study, planning and analysis, and concept through preliminary design for a new downriver greenfield electrified/automated container terminal. Situated closer to the mouth of the Mississippi River than the existing terminal, the new terminal will not have any air draft restrictions. The siting study initially evaluated six alternative locations, with more detailed analyses performed for the two primary options to ultimately select the preferred site located in Violet. For this site, AECOM performed planning analyses and simulations and developed conceptual plans to evaluate alternative layouts for both electric RTGs and automated stacking cranes (ASCs); ASCs were selected for development of a fully automated terminal.



AECOM developed conceptual through preliminary design for the proposed new 290-acre terminal that, with full-build-out, will be capable of handling more than 2M TEUs and include site preparation and ground improvement (to raise site grades), 3-berth wharf including barge berth, container stacking, reefer racks, on-dock intermodal yard, truck entry/exit gate facilities, and terminal buildings for administration, operations and maintenance. The marine infrastructure for Phase 1 is being advanced into detailed design and will include a pile-supported wharf and platform extending into the Mississippi River, new flood walls on the levee and ramps to provide access to the terminal over the levees, with consideration for shore-to-ship power.

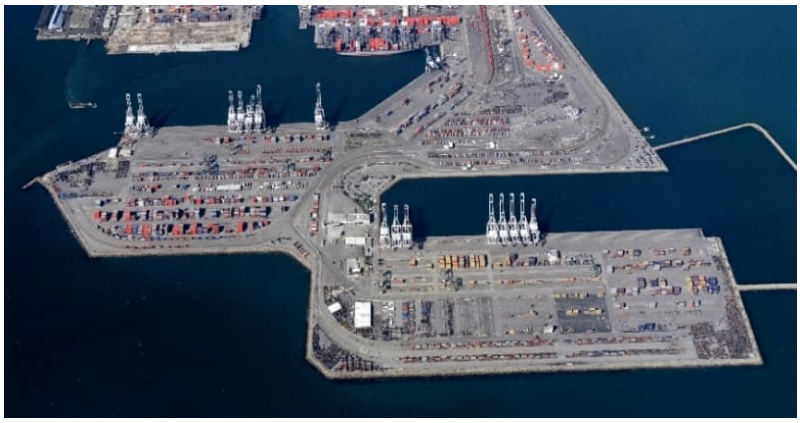
Berth F208, Mitsubishi Cement Terminal Upgrades & Expansion, Port of Long Beach, California



AECOM performing planning, geotechnical, environmental, engineering and design, and construction support services for expansion of this terminal. The development will include four new 10,000-ton cement storage silos and supporting conveyance systems and infrastructure. Construction of Phase 1was completed, which included seismic upgrade of the steel sheetpile cellular bulkhead system with installation of stone columns behind the bulkhead, improvement of wharf infrastructure, relocation of utilities and upgrade of site infrastructure, new electrical systems for a ship emissions carbon capture system, and a new shore-to-ship power system for dry bulk carriers. This is the only known active bulk carrier shore power system in North America.

Terminal Equipment Decarbonization

Pier J Container Terminal Zero-Emissions Infrastructure Master Plan Scoping Study, Port of Long Beach, California



AECOM developed a Project Scoping Document for the Port for a Zero Emissions Infrastructure Master Plan for the Pier J Container Terminal to lay the groundwork for deployment of appropriate zero-emissions technologies and equipment capable of meeting operational requirements. The goal of the study was to address the many challenges associated with the transition to zero emissions, such as a lack of heavy-duty charging standards, limited market availability of zero-emission equipment, operational and physical constraints at marine terminals, and the significant investment required in equipment and charging and fueling infrastructure. The study included evaluation of peak electrical demands today and in the future with the charging of electrical equipment to assess and size the capacity of power distribution infrastructure.

Assessment of Zero-Emissions Container Equipment, Port of Oakland, California



AECOM performed an assessment of options for the Port to convert a representative container terminal from diesel-powered container handling equipment and drayage trucks to zero emissions technologies. Battery-electric vehicles and on-terminal tractors were found to be the most technically mature options. The study included estimation of expected electric use and comparison with existing overall terminal electrical use, projection of future costs for these vehicles based on expected declines in battery costs and increasing economies of scale of manufacturing, and evaluation of life cycle cost benefits due to lower operating costs of electric vehicles to help the Port understand the magnitude of utility investments required over time.

Shore-to-Ship Power Systems

Royal Caribbean Cruise Shore Power Program, Worldwide



AECOM is providing engineering services to Royal Caribbean for implementation of shore power systems a cruise terminal location around the world. Services have included performing feasibility studies, concept development, cost estimates, and engineering design. Feasibility studies have included evaluation of power sources, electrical distribution system and berth cable management systems for development of concepts and costs to implement shore power.

AECOM is currently performing feasibility studies for implementation of shore power systems at multiple cruise terminal locations as part of RCCL's first phase of their cruise shore power program. Terminals included in the study are located in the US (Alaska, Florida, New Jersey), Mexico, Italy and Greece. The terminals include berths that are dedicated to RCCL, as well as shared with other cruise lines.

Pier T Container Terminal Shore Power Project, Port of Long Beach, California



AECOM performed planning and conceptual design, final design, plans, specifications, estimates, testing and commissioning support, and construction support to provide shore-to-ship power for all five berths at the Pier T Container Terminal, which is the largest deep water container terminal in the Port of Long Beach. This project required extensive upfront planning and coordination as new systems were installed within an active container terminal that services a wide range of container ships. The design included distributing power from the main terminal substation at 25 kV to new shore power substations for each of the five berths. Each substation included a 25 kV to 6.6 kV step-down transformer, main circuit breaker, and minimum four feeder circuit breakers to power five 6.6 kV receptacles at each berth.

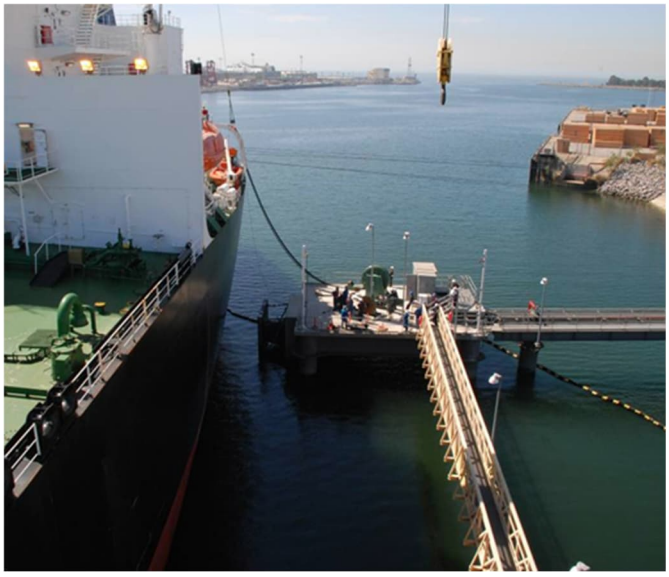
Pier J Container Terminal Shore-to-Ship Power Retrofit Project, Port of Long Beach, California



AECOM, as a subconsultant, provided planning, civil, structural, geotechnical, and environmental engineering services to upgrade the Berths J245-J247 and J266-J270 container wharves (four berths) to provide shore-to-ship power systems. The project included new shore power substations at each of the four berths and extensive new electrical duct banks throughout the terminal to connect the shore power outlets to the terminal's main substation, which included connection to a new 12 kV substation outside the terminal and jack-and-bore construction to convey new conduit under the on-dock intermodal yard.

Berth T121, Petroleum Marine Terminal Shore Power Project, Port of Long Beach, California

AECOM performed planning, engineering, design, permitting, bid and construction support, and commissioning services for implementation of shore power systems for the Alaska Class Tanker Ships at the Berth T-121 marine oil terminal in the Port of Long Beach. This is the world's first (and only) petroleum terminal shore power system, with the first ever connection of an oil tanker performed on November 9, 2008.



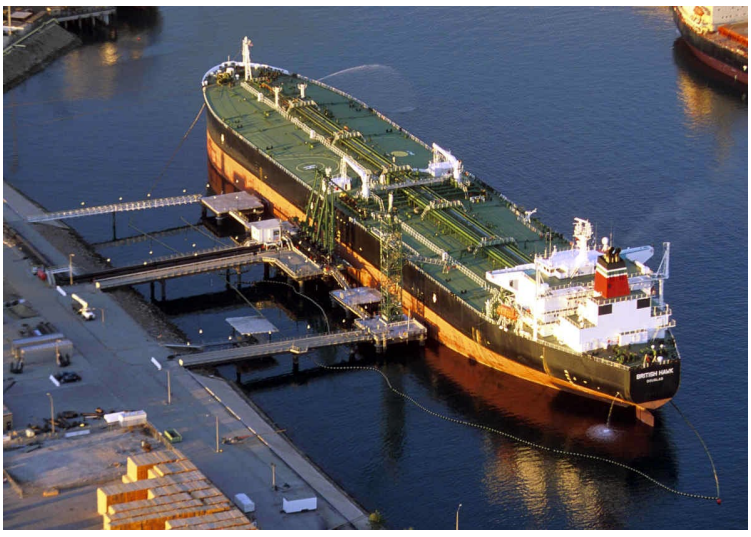
The project included a new marine platform in 80 feet of water to support the fixed cable management system and switch gear, new utility and access trestle and catwalk, and new electrical distribution system from a new onshore substation out to the marine platform to provide 8 MW of shore power at 6.6 kV for the vessel connection. The power cable connections are raised and lowered to the ship with the ship's crane. The substation equipment was designed to account a fluctuating power demand from the tanker during product unloading.

Vessel Decarbonization

Marathon Petroleum Vessel Carbon Capture Program, California

AECOM were appointed by Marathon Petroleum to perform feasibility studies and develop concept designs for capture and control of emissions from berthed liquid bulk vessels at their offloading terminals within the Port of Long Beach (POLB) and at the Martinez refinery in California. The work is being performed to allow the marine facilities to be compliant with air quality requirements developed by the California Air Resources Board (CARB). The project includes the review of both waterborne and land-based installations to capture emissions from bulk oil tanker vessels, ranging from MR size to VLCCs. Bulk oil tanker vessels are required to run their auxiliary engines while at berth to pump petroleum products, releasing high levels of emissions within the Port and coastal environment. The project looks to capture these emissions until facilities and tanker vessels can be fitted or developed to accept shore power. The facilities for carbon capture include cranes and processing units which are electrically powered.





AECOM's scope of work included developing options and concept designs for carbon capture for all marine facilities, which included: Berth T121, LBT Berths 84A and 86, and Terminal 2 Berths 77 and 78 (5 berths) in POLB and the Avon Wharf in Martinez. Development of the options included discussions with vendors for the capture and control equipment (cranes, barges, scrubbing/processing plant) to use the most current technology and trends in the market. For each option, AECOM developed cost estimates for procurement of the equipment, construction and installation, and operations. The findings from the options study at each berth was captured in a basis of design document, along with layouts, pros and cons, cost estimates, and recommendations.

The POLB facilities include self-propelled and self-contained waterborne barges that would use onboard telescopic cranes to lift capture hoods over the vessel's emissions stacks, scrub the air to eliminate hazardous compounds, and then release clean air. The barges would move into place following the tanker vessel completing berthing maneuvers, before offloading operations begin. The POLB options included construction and installation of land-based capture cranes and control units and new in-water platforms to house the capture and control equipment. Development of options included: high-level assessments of where power could be supplied to the new systems from within the existing terminals; the type of electrical

upgrades which would be needed to allow the systems to be feasible; and analysis of the range and volume of emissions from each different type of vessel. Options were refined during workshops at which the utilization, constructability, operations, maintenance, permitting, and cost were discussed.

Options for the Avon wharf at the Martinez refinery did not include land-based solutions, as the wharf is situated offshore and accessed via a jetty. Options were developed for self-propelled, self-contained barges, and tug assisted self-contained barges, as well as the capture and control equipment being based on new in-water platforms. Options were refined using a similar process/workshop as those for the proposed new systems at POLB.

Delta Ferries Feasibility Study, Solano County, California



AECOM performed a study for the California Department of Transportation (Caltrans) to investigate options to replace two existing diesel car ferries with either a bridge or an electric (zero emissions) ferry solution. The ferries currently provide transportation to and from Ryer Island in Solano County and serve as an extension of the California roadway network in the Sacramento Delta. This study consisted of developing life cycle cost models for each option that included all expected costs of procurement and operations, as well as accounting for the value of customer time (ferry journeys take longer than bridge journeys). As part of this study, AECOM analyzed the expected ferry battery size, charging rhythm, likely charger capacity requirements, charging equipment, and potential renewable power solutions to support vessel charging, such as solar arrays and battery systems.

Alternative/Renewable Power

Hydrogen Trigeneration Project, Pier B Toyota Terminal, Port Long Beach, California

The first commercial-scale SureSource Hydrogen Trigeneration system was deployed at the Port of Long Beach. FuelCell Energy, Inc. has been expanding its commercially deployed Molten Carbonate Fuel Cell (MCFC) technology to arrive at a process that generates electricity, high-purity hydrogen and thermal energy from directed biogas. This process, known as the SureSource H2 Trigeneration system, has been successfully demonstrated twice at sub-MW scale.



The system uses directed biogas from an existing pipeline as the fuel, and the high-purity and moderate pressure hydrogen is being utilized by Toyota in fuel cell-based cars and trucks offloaded at the port. The system can produce up to 1,270 kg/day of green hydrogen and generate up to 2.3 MW of electricity, up to 0.5 MMBtu/hr of thermal energy, and water.

All will be used by Toyota with the remaining excess electricity sold to Southern California Edison (SCE) under California's BioMAT feed-in tariff program. AECOM provided detailed engineering and design services for the Front End Engineering Design (FEED) phase for this project, which included civil, structural, mechanical, electrical, instrumentation and controls, as well as through the procurement, fabrication, construction, and deployment phases of the project.

World Cruise Center Rooftop Solar Project, Port of Los Angeles, California

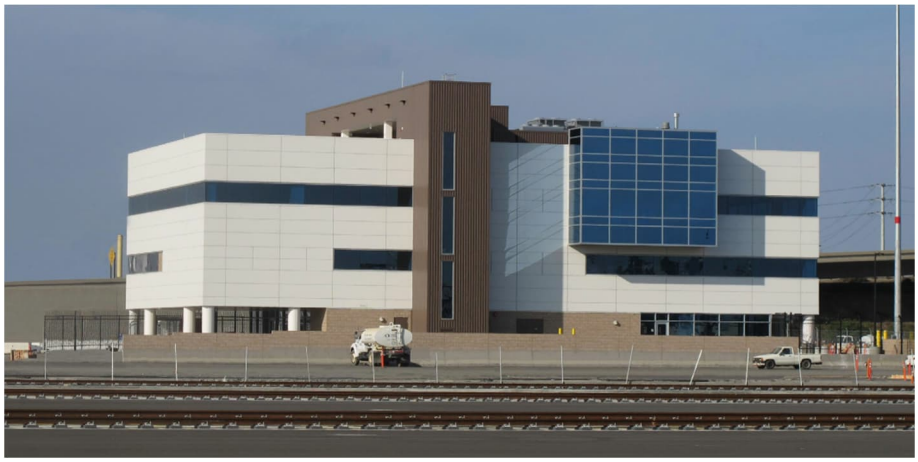
AECOM assessed feasibility and performed planning, permitting and preliminary design for installation of a 1 MW roof-top photovoltaic solar system for the Berths 93A-93B World Cruise Terminal Building. The scope included identification of potential support systems, evaluation of the efficiency of power conversion, identification of the best locations for solar panel installation, and evaluation of the building's structural capacity. Preliminary concepts were developed for a structural framing system and layouts for installation of an "attached" roof-mounted solar power system in accordance with building and fire department requirements. A Photovoltaic Roof Plan was developed to show placement of solar panels on the building's 40,536 square foot roof and details for installation, which were used by the Port for design-build project to install an "unattached" roof-mounted system.



Terminal/Building Sustainability

Long Beach Container Terminal Operational Buildings, Port of Long Beach, California

AECOM provided full design and construction support services for new operational buildings as part of the $1.3B Long Beach Container Terminal Development, the first fully automated terminal in the Port of Long Beach. The buildings designed by AECOM included: 32,000 SF Terminal Operations & IT Management Building housing the control systems for the entire automated terminal; 14,600 SF Battery Exchange Building; 13,000 SF Marine Operations Building; 50,000 SF Power & Crane Maintenance Shops; 28,000 SF Chassis Maintenance Shop; 12,000 SF Genset Repair & Reefer Wash Building; 20,000 SF Roadability Building; and 3,000 SF Storage Structure. Four of the buildings were certified as LEED Gold or Silver and the project included 63,000 SF of PV-solar carports.





The fully-automated 14,600 SF Battery Exchange Building was a unique first-of-its-kind building designed to house large storage racks for batteries intended to be charged and robotically exchanged in and out of automated guided vehicles (AGVs) used within the container yard. Precise construction tolerances were necessary for the movement of AGVs and robotic equipment and a robust mechanical system was required. The mechanical, fire protection, building management, and battery management systems were all coordinated and interconnected to control production of hydrogen gas and heat by the charging system and to meet novel fire hazard conditions.

Security Command and Control Center, Port of Long Beach, California

The Ports of Long Beach and Los Angeles form the largest active port complex in the United States, providing maritime shipping services and products that affect commerce throughout the country, which makes this port complex a potential target for terrorism. The Port of Long Beach secured funding from the Department of Homeland Security, Transportation Security Administration (TSA) to design, construct and share a new Security Command and Control Center to be located within the Port a centralized location to facilitate port-wide security monitoring operations. The center's intent is to enhance physical security of the LA/LB ports to a reasonable level that decreases the likelihood of disruption to normal operations.



The $21 million center was awarded Silver-level certification and the first building in the Long Beach Harbor District to earn a U.S. Green Building Council Leadership in Energy and Environmental (LEED®) certification. The center's 25,000 SF main building features broad windows that allow in as much natural light as possible and sensor switches that only turn on electric lights when they detect movement. The carpeting is made from 30 to 40 percent recycled material. Outside, the pavement that surrounds the building is made from permeable material that allows water to seep in, decreasing runoff water into storm drains and eventually the ocean.

AECOM led the planning and programming phase, which included evaluation of potential sites that could provide land, water, and air (helicopter) access and development of the facilities and requirements that would meet the needs of port security as well as the specialized requirements of individual enforcement agencies. During the design phases, AECOM led the site civil engineering and design, which included realignment of Pier F Avenue, relocation of existing natural gas and water utilities, grading and paving (included LEED® compliant paving), utilities to building (sewer, water, gas, storm drain), parking (standard, ADA & compact spaces), perimeter security fencing, trash enclosures, curbs, and site ingress/egress. AECOM was also the project's Sustainable Design Specialist, which included the LEED® certification process for the main building.

North Bulkhead Cruise Berths 1-6 Replacement, PortMiami, Florida

AECOM is providing owner's representation service to the Port, as part of ongoing program management services for implementation of the Port's Capital Development Program. This proposed design-build-finance project involves replacement of over 7,100 feet of deteriorating steel sheet pile bulkhead with installation of pre-cast concrete caissons in front of the existing bulkhead, extending the bulkhead line into the navigation channel, widening and upgrade of the apron, new passenger boarding bridges and runway modifications, new berthing and mooring systems, water stations, and shore-to-ship power systems. Currently in the preliminary design phase, the Port intends to obtain Envision certification for this project. AECOM developed a Sustainability Management Plan and initial Envision scorecard for the project outlining the necessary steps to achieve certification. The sustainability goals for the project included: monitoring of the existing seawall to prevent collapse throughout the duration of the project; maximizing operational efficiency; providing a safe work area during operations; reduction of emissions; and preservation of marine life potentially affected by the project.



Offshore Wind Terminals

Crowley Wind Marshaling Terminal, Port of Salem, Massachusetts

AECOM team provided planning, engineering, design, and grant funding services for redevelopment of a 42-acre former power plant brownfield site as a Wind Port in the City of Salem, MA. AECOM performed planning and prepared conceptual through detailed design packages, including design drawings for inclusion in permit applications, for waterfront and upland infrastructure improvements to accommodate the staging, storage, marshaling and assembly of offshore wind components for several wind farms in the Northeast U.S. Infrastructure. AECOM also prepared the grant application for a PIDP grant award of $35M and prepared the framework for Envision verification of the project, which included an Envision preliminary assessment and establishing the level of achievement targets for each targeted credit. The primary components of the project include:





- Wind Turbine Installation Vessel (WTIV) Main Berth – New heavy-lift pile-supported platform, partial demolition of existing wharf structures, dredging and seabed preparation for WTIV vessel jackup vessels with very large loading, new berthing and mooring dolphins and shore-to-ship utility and power services.
- Ro-Ro Berth – New heavy-lift pile-supported platform for the ramps of Ro-Ro vessels, including partial demolition of existing wharf, dredging and seabed preparation and shore-to-ship utility and power services.
- Jetty Wharf (Delivery Vessel Berth) and Jetty Wharf Trestle – New pile-supported heavy-lift platform for required load bearing, new in-water dolphins, dredging and shore-to-ship utility and power services.
- Pre-Assembly & Loadout Platform – New pile-supported heavy-lift platform for pre-assembly and loadout of WTG components.
- Laydown area and Transition Yard – 32-acre laydown area for Nacelles, Blades and Towers storage, ground improvements of the laydown areas and SPMT pathways for transportation and storage of WTG components. Regrading and DGA design of the entire site to achieve final grades and required bearing capacities, demolition of existing buildings, installation of new electric, storm, wastewater and potable water utilities and paving.
- Cruise Terminal – Included provisions within the terminal design for expansion of the adjacent cruise terminal and berth, including installation of distribution system for cruise vessel shore-to-ship power connections at the berth.

State Pier Wind Terminal Development, New London, Connecticut

AECOM has been supporting the Connecticut Port Authority (CPA) to undertake site and infrastructure improvements for the 30-acre State Pier in New London. These improvements will transform the pier into a heavy-lift capable marine terminal that will accommodate a wide variety of cargoes, including offshore wind turbine generator staging and assembly. The proposed State Pier infrastructure improvements are designed to address previously identified facility shortcomings and enhance the State Pier facility and site conditions to accommodate future cargo needs and capitalize on opportunities for the State. AECOMs services included: program management; environmental impact, assessment and permit application/approvals; port planning; independent review of all design documents and submittals; evaluation of value engineering alternatives; cost estimating and master project milestone schedule development/management; construction management at risk procurement; and construction administration. Infrastructure improvements were categorized into the following five primary components:





- Uplands – Excavation of substantial portions of the site to achieve final grades, demolition of existing buildings, installation of new electric, storm, wastewater and potable water utilities and paving.
- Northeast Bulkhead (Delivery Vessel Berth) – Demolition of existing pier platform and in-water dolphins, dredging and seabed preparation and construction of new bulkhead, pile-supported platform and shore to ship utility services.
- State Pier (Installation Vessel Berth) – Partial demolition of existing pier structures, installation of new king pile system, heavy-lift pile-supported platform, dredging and seabed preparation and shore-to-ship utility services.
- Central Wharf – Land reclamation via new king-pile system connecting State Pier with CVRR Pier, combined with beneficial reuse of dredge sediments and on-site fill material.
- Remediation – Consistent with the approved RAP, addressed several areas of concern in advance of and in collaboration with redevelopment activities.

South Brooklyn Marine Terminal, Brooklyn, New York

AECOM has been overseeing redevelopment and reactivation of the 73-acre South Brooklyn Marine Terminal located in Sunset Park, Brooklyn. The terminal will be a multi-purpose offshore wind support facility that will include a Wind Turbine Generation component staging yard, multiple operation and maintenance bases and New York City's largest substation. The project site has been dormant and mostly inactive for the past 30 years. Significant work was required to reactivate the site to accommodate loading and offloading offshore wind components that require bearing capacities considerably higher than traditional maritime facilities. The $250M project involved reconstructing or repairing multiple bulkheads, two new heavy-duty crane platforms, two new maritime vessel platforms, dredging five distinct berths and access to the federal channel, overall site work (including repaving, regrading, stormwater management and utilities), and all site preparation work related to the buildings to be constructed on site.

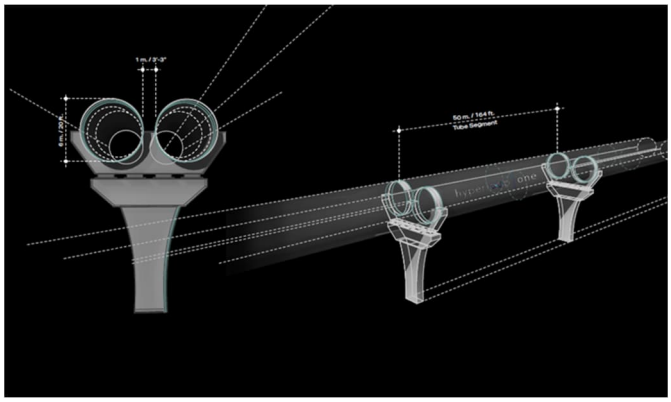


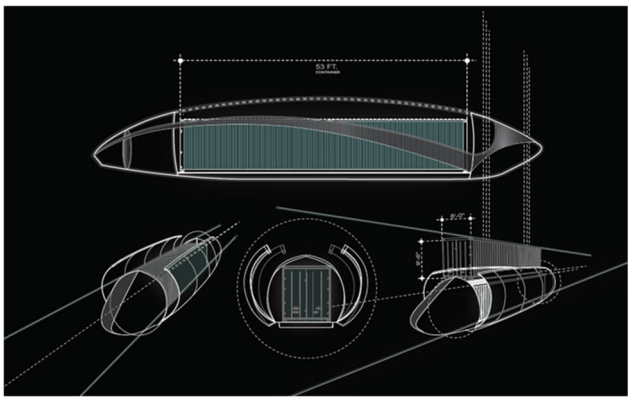
AECOMs services included: program management; initial site assessment; feasibility study; preliminary engineering; environmental assessment; environmental permitting; cost estimating; benefit cost assessment; risk management; project scheduling; and oversight of the development of multiple federal and state grant applications. AECOM worked with multiple stakeholders to support the port improvement plan for the dormant site on critical real estate. AECOM also planned and designed the port facility for the first user (offshore wind developer) while accommodating future users such as container terminals and breakbulk, as well as a limited area to support the offshore wind developer's operation and maintenance program for multi-purpose users.

Alternative Transportation Systems

Hyperloop Technology Feasibility Study for Cargo Movement, Ports of Los Angeles/Long Beach

AECOM performed a Feasibility Study with Virgin Hyperloop One to assess the viability of using Hyperloop technology for movement of cargo from ports as an alternative to truck and rail, using the Ports of Los Angeles and Long Beach as a case study. Hyperloop is an autonomous vehicle that will levitate within tube with a low-pressure environment and glide at faster-than-airline speeds over long distances using an electromagnetic propulsion system. AECOM provided technical support to Virgin Hyperloop One for development of the Hyperloop technology, including propulsion, levitation, braking, vacuum, tube, airlock, and power systems. Initial work involved evaluation of the technology for several applications in the transportation industry, including cargo and passenger movement.

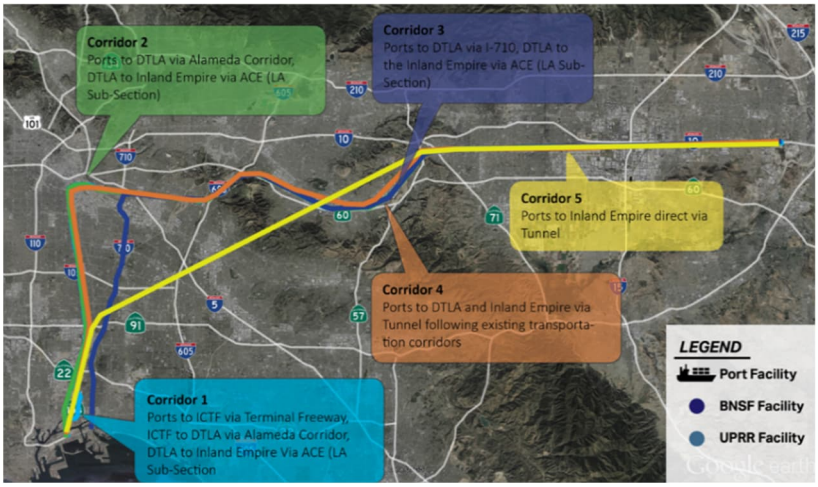




The Study focused on transportation of containers from the 13 marine terminals within the Port complex to inland railyards operated by the BNSF and Union Pacific railroad companies within the Los Angeles Basin for distribution to the national rail network. The Study also evaluated other potential locations within the Los Angeles Basin for local distribution of cargo to warehousing centers and regional distribution within the southwest U.S. The goals of the study were: applicability of the technology for transportation of cargo; effectiveness of the system to handle and efficiently transport cargo; and economic viability for implementation of the technology. The scope of work included:

- Assessment of the Hyperloop technology, and other supporting technologies, that will be used to transport containers, including evaluation of the technology equipment and requirements, advantages and benefits, and limitations and constraints.
- Evaluation of the goods movement (cargo) operations that transport containers (by truck and rail) from the Port complex to the inland intermodal yards in order to determine how the Hyperloop technology could be utilized within this transportation network.
- Development of requirements for a Hyperloop system that would effectively and efficiently transport cargo to/from the Port complex, which included: system capacity, size, and configuration; infrastructure and facilities; and operational approach and concept.

- Evaluation of the various equipment and technologies to determine the most effective cargo handling systems and operations to load/unload the Hyperloop system.
- Development of preliminary loading/unloading terminal sites and routes for the Hyperloop guideway between the Port complex and proposed inland end points.



- Preparation of high-level capital and operation costs for the Hyperloop guideway system.
- Assessment of the environmental benefits resulting from use of a Hyperloop system and identification of the primary stakeholders, right-of-way issues and approvals required for implementation of the system.

Zero-Emission Container Transport Technology Study, Ports of Los Angeles/Long Beach

AECOM, as a subconsultant, evaluated a range of zero-emission container transportation technologies to assess technical and commercial readiness for deployment in revenue service for the Ports of Los Angeles and Long Beach. The objective of this assessment was to identify technologies that were market ready and technically appropriate for a fully functioning service demonstration, carrying marine containers between port marine terminals and inland intermodal transfer facilities.





The assessment was performed in two phases. Initial assessment entailed identifying the broadest known range of alternative technologies and their proponents and characterizing their approaches to the market. The range of technologies included retrofits to conventional rail, linear induction monorail, magnetic levitation and lighter-than-air transport. The information gained from this assessment, while necessarily subjective, revealed a great deal about the depth of understanding of each of the technologies and their commercial maturity. In a second phase, AECOM prepared a rudimentary performance specification as the basis for a technical inquiry. The responses to this inquiry enabled a more detailed and rigorous comparison of the alternative technologies. The findings of this assessment provided a basis for a more substantive comparison of technical and commercial readiness for deployment.

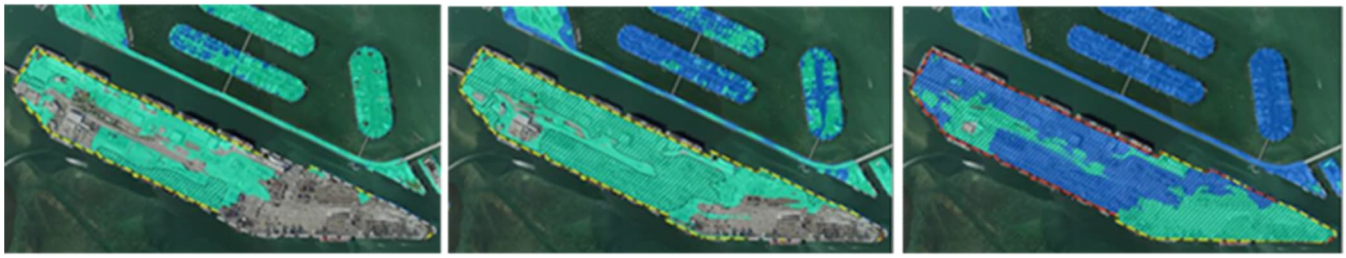
Climate Change/Sea Level Rise Vulnerability Assessments

PortMiami Sea Level Rise Vulnerability Assessment and Adaptation Study, Florida

AECOM developed of a port-wide SLR vulnerability assessment and adaptation study for PortMiami. The Port serves a vital role for the local economy of South Florida, providing a critical intersection point of the regional and global commerce and supply chains. Located in Biscayne Bay, much of the Port's infrastructure was designed to operate under a range of historical environmental conditions (i.e., tide levels, storm surge elevations, storm frequency, etc.) that are likely to change in the future due to climate change. This poses potential vulnerabilities to Port infrastructure and operations from future weather extremes and climate change, particularly due to sea level rise. The results of the study will assist the Port in increasing their resilience to future flood events and strengthen their ability to remain a strong economic engine locally, regionally, and nationally.



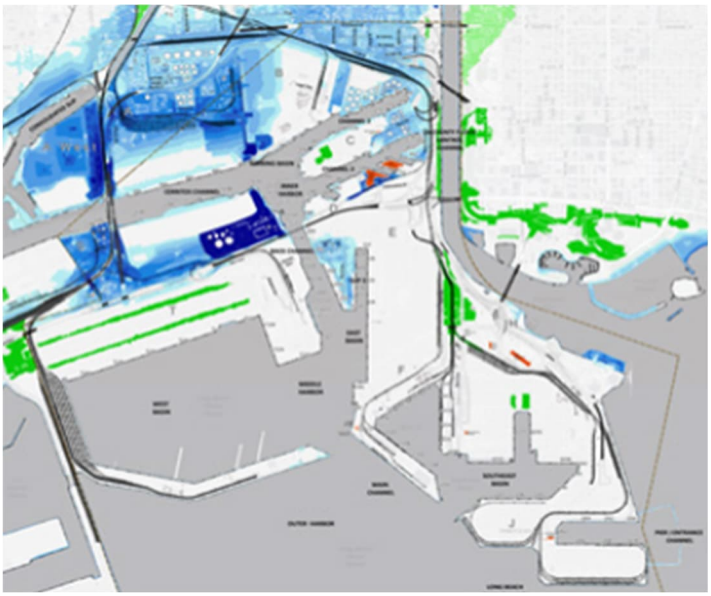
AECOM examined the susceptibility of the Port's assets and operations to flood and wave impacts over a range of potential SLR scenarios through 2120. This included a review of the best available SLR science, an inventory of Port assets, and detailed mapping of SLR, storm surge, and wave action extents. Assets identified as exposed to future SLR and wave impacts were also assessed for sensitivity, adaptive capacity, consequence of failure, and impact costs to develop a means for prioritization and resource allocation of potential adaptation projects. A "toolbox" of strategies was developed for phased implementation to increase long-term flood resilience. Adaptation strategies included physical (e.g., traditional engineered flood protection and infrastructure modifications) and non-physical (e.g., updating minimum design standards or additional studies to fill data gaps) approaches to provide a holistic level of SLR and flood resilience.



Capital planning design guidance was developed to completement the strategy toolbox, providing a framework for consideration and selection of appropriate SLR scenarios within the Port's capital planning process based on the project's risk tolerance, lifespan, criticality, and adaptability. Under this framework, SLR guidance was developed for the North Bulkhead Cruise Berths 1-6 Realignment project, that will reconstruct over 7,100 feet of deteriorating steel sheetpile bulkhead, to provide an adaptable design approach for SLR that may occur over the project's 75-year design life.

Climate Adaptation and Coastal Resiliency Plan, Port of Long Beach, California

AECOM developing the Climate Adaptation and Coastal Resiliency Plan Study for the Port to manage the risks associated with climate change and coastal hazards that could cause direct or indirect consequences to infrastructure and operations over the next century. The study was performed in two parts: (1) Climate Change Study, consisted of performing a climate science review, inventory of assets, sea level rise and storm surge mapping, and development of vulnerability profiles for critical assets; and (2) Climate Adaptation Coastal Resiliency Plan, which identified mitigation strategies for infrastructure on the wharves, piers, the transportation networks (roadways and railroads), critical buildings, utilities and breakwater. Critical elements of the study included:



- Climate Change Stressors and Impacts: Detailed climate science review to examine international, national, and local data covering sea level rise and storm surge, overtopping, extreme temperature and wind, precipitation, and ocean acidity change.
- Port Asset Inventory: Inventory of assets at the Port, which included the facilities at each pier, wharf and backland assets, utilities, roadways, rail assets and critical buildings such as those housing security, administration, fire and life safety functions.
- Sea level Rise and Storm Surge Maps: Creation of inundation maps that considered various levels of SLR, extreme tide and storm surge inundation of the Port property, overtopping of existing shoreline structures, and the projected impact of riverine flooding.
- Vulnerability Profiles: Developed vulnerability profiles for Port assets, which assessed the level to which each asset is exposed to a climate impact combine with its sensitivity to that impact, as this provides a basis for establishing priorities.

Sea Level Rise Adaptation Study, Port of Los Angeles, California

AECOM performed a study to assess the impacts of SLR for the Port that included: (1) Assessment of the impact of SLR in the years 2030, 2050, and 2100, as well as 100-year storm events, on Port lands; (2) Estimate of the financial cost of the impact of SLR on Port lands that considered the potential cost of repair of damage to and the value of lost use of improvements and land, and the anticipated cost to prevent or mitigate potential damage; and (3) Description of how the Port proposes to protect and preserve natural and manmade resources on Port and mitigate impacts of SLR. The study included:



- Climate Science Review and Impacts: Assessed each climate change and coastal hazard parameter to address Port's existing and future activities through various stages of operations, planning design construction and maintenance., and identify potential SLR impacts.
- Infrastructure and Operations Inventory: Inventory of Port infrastructure and operations so all appropriate combinations of assets and operations would be analyzed for vulnerability and risk.
- Inundation maps: Preparation of maps for various SLR, tide and storm surge scenarios, and overtopping analysis to identify the most vulnerable areas for adaptation strategies.
- Vulnerability Assessment: Assessed vulnerability for each asset type with respect to exposure, sensitivity (remaining life, purpose and cost to adapt) and adaptive capacity.
- SLR Resiliency Strategies: Developed series of adaption solutions to the predicted impacts of SLR across the built, natural and social environments linked to the Port. Strategies included: governance (addresses port-wide planning and design documents), initiative (addresses informational gaps), and infrastructure (addresses physical vulnerabilities). A workshop was performed with the Port to determine which strategies would be considered an immediate priority, a future consideration, or omitted.
- SLR Study: Developed the SLR plan, with the climate resilient vision for the Port, addressing all relevant infrastructure and operational activities expected to be affected by SLR, and the adaptation strategies the Port could start to consider for incorporation.