Berkeley Public Policy
The Goldman School

Center for Environmental Public Policy

Final Report

Maritime Port Clean Energy Infrastructure Jobs Study

David Wooley[1], Betony Jones[2], Alyssa Cheung[3], and Jerold Brito[3]

Prepared for Ocean Conservancy

July 30, 2021

Introduction

The Ocean Conservancy asked the Goldman Center for Environmental Public Policy to estimate jobs associated with infrastructure spending on projects to reduce air pollution and greenhouse gas emissions from major maritime port operations in the U.S. This document summarizes our inputs, methods, and estimates of total jobs created.

This request coincides with a number of infrastructure proposals in Congress, some of which include funding for port infrastructure. Pollution from maritime port operations, which are currently powered mostly by diesel and heavy oil, have adverse impacts on communities near ports. These impacts fall

[1] Director and Lecturer, Environmental Center, Goldman School of Public Policy, UC Berkeley.
[2] Founder and Principal, Inclusive Economics, Oakland, CA.
[3] Graduate Student Researchers, Goldman School of Public Policy, UC Berkeley.

disproportionately on people of color.[4,5,6,7,8,9] For this reason, funding for maritime port infrastructure should prioritize projects that reduce emissions from fuel combustion. In one action, Congress could produce jobs, improve public health, achieve greater equity for disadvantaged communities, reduce greenhouse gas emissions, and lower long-term freight costs.

There is a wide range of actions ports could take to reduce emissions and fuel costs. Some options, including changes in ship and rail propulsion, involve emerging technology and systems that are not yet market-ready; however, they need and deserve support for planning and research.[10] In this report we address a selection of port infrastructure projects that are possible today or in the near future.

Many of the port infrastructure projects examined in this report involve port electrification, a key strategy to address environmental pollution that has long plagued port-adjacent communities. Nearly 39 million people live near ports in the United States.[11] Due to decades of discriminatory planning policies and zoning, many port-adjacent neighborhoods are home to communities of color and low income communities. Diesel-reliant port equipment and freight trucks impose heightened exposure to harmful emissions, including nitrogen dioxide, diesel particulate matter, black carbon, and fine particulate matter in these communities.[12,13] Individuals exposed to these pollutants suffer from elevated rates of respiratory and cardiovascular diseases, cancer, impaired child development, and premature death.[14,15] For example, an analysis of asthma rates in Long Beach found that 1,600 cases of childhood asthma in

---

[4] Joshua Apte et al., "High-Resolution Air Pollution Mapping with Google Street View Cars: Exploiting Big Data," *Environmental Science & Technology* 51, no. 12 (June 5, 2017): 6999–7008.
[5] Rachel Morello-Frosch, Manuel Pastor, and James Sadd, "Environmental Justice and Southern California's 'Riskscape': The Distribution of Air Toxics Exposures and Health Risks among Diverse Communities," *Urban Affairs Review* 36, no. 4 (March 1, 2001): 551–78.
[6] California Air Resources Board, "Summary: Diesel Particulate Matter Health Impacts," accessed July 28, 2021, https://ww2.arb.ca.gov/resources/summary-diesel-particulate-matter-health-impacts.
[7] Xiao Wu et al., "Fine Particulate Matter and COVID-19 Mortality in the United States," *Science Advances* 6, no. 45 (November 4, 2020), https://projects.iq.harvard.edu/covid-pm/home.
[8] Environmental Defense Fund, "How Pollution Impacts Health in West Oakland," accessed July 28, 2021, https://www.edf.org/airqualitymaps/oakland/pollution-and-health-concerns-west-oakland.
[9] Jesse N Marquez, "Importing Harm: U.S. Ports' Impacts on Health and Communities" (THE Impact Project, January 2012), http://envhealthcenters.usc.edu/wp-content/uploads/2016/11/Impact-Project-Ports-issue-brief-2012-1.pdf.
[10] Charles Haskell, "How Ports Can Be the Catalyst for Shipping's Zero-Carbon Transition," *Lloyd's Register Horizons*, July 2021.
[11] Office of Transportation Air Quality, US Environmental Protection Agency, "National Port Strategy Assessment: Reducing Air Pollution and Greenhouse Gases at U.S. Ports," September 2016, https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100PGK9.pdf.
[12] Office of Transportation Air Quality, US Environmental Protection Agency.
[13] Douglas Houston, Margaret Krudysz, and Arthur Winer, "Diesel Truck Traffic in Low-Income and Minority Communities Adjacent to Ports," *Transportation Research Record: Journal of the Transportation Board Research*, December 1, 2008, https://doi.org/10.3141/2067-05.
[14] Office of Air and Radiation, US EPA, "Environmental Justice Primer for Ports: Impacts of Port Operations and Goods Movement," Overviews and Factsheets, July 31, 2019, https://www.epa.gov/community-port-collaboration/environmental-justice-primer-ports-impacts-port-operations-and-goods.
[15] Paul Allen et al., "Newark Community Impacts of Mobile Source Emissions" (M.J. Bradley & Associates, November 2020).

the port community were attributable to traffic proximity, and that eliminating ship emissions would eliminate 1,400 asthma-related bronchitis episodes.[16] The California Air Resources Board (CARB) estimated that activities at the Ports of Los Angeles and Long Beach alone resulted in 67 premature deaths per year.[17]

The same CARB study found that statewide economic losses from premature deaths, coupled with the costs of medical care, missed school, and skipped work days, totaled $19 billion per year in 2005.[18] With over 360 commercial ports in the United States, the cost of *not* investing in port electrification may end up being far more expensive than continuing to rely on diesel-powered port equipment and trucks.[19] The health benefits and associated cost savings from electrifying ports can be achieved at relatively low upfront costs.[20, 21]

Many logistics companies have recognized the advantages of adopting electric trucks into their fleets. Fuel costs comprise approximately 52% of the total cost of ownership (TCO) over the lifetime of a diesel truck.[22] Electricity has long had a price advantage over diesel, and electricity prices have been less volatile over time.[23] Lower fuel costs and decreasing battery prices are bringing the TCO of electric trucks and diesel trucks close to parity. In fact, recent studies indicate that TCO parity has already been achieved, with a cost advantage of electric trucks growing over time.[24]

The transition towards cost-efficient, low-carbon goods movement has the potential to put significant downward pressure on shipping costs, through reduction in operating costs. For example, moving away from diesel engines will reduce fuel costs, thereby reducing operating costs.[25] Workhorse Group estimates that the electrification of all last-mile deliveries would amount to $540 million in fuel savings

---

[16] Laura Perez et al., "Global Goods Movement and the Local Burden of Childhood Asthma in Southern California," *American Journal of Public Health* 99 (March 10, 2009).
[17] California Air Resources Board, "Emission Reduction Plan for Ports and Goods Movement in California," April 20, 2006.
[18] California Air Resources Board.
[19] Office of Air and Radiation, US EPA, "Ports Primer: 2.1 The Role of Ports," Overviews and Factsheets, September 18, 2016, https://beta.epa.gov/community-port-collaboration/ports-primer-21-role-ports.
[20] Amol Phadke et al., "2035 Report" (Goldman School of Public Policy, April 15, 2021), https://www.2035report.com/transportation/downloads/.
[21] Amol Phadke et al., "Why Regional and Long-Haul Trucks Are Primed for Electrification Now" (Lawrence Berkeley National Laboratory, March 2021), https://eta-publications.lbl.gov/sites/default/files/updated_5_final_ehdv_report_033121.pdf.
[22] California Air Resources Board, "Advanced Clean Trucks Total Cost of Ownership Discussion Document - Preliminary Draft for Comment," February 22, 2019.
[23] Jessica Leung and Janet Peace, "Insights On Electric Trucks For Retailers And Trucking Companies" (Center for Climate and Energy Solutions, February 2020).
[24] Phadke et al., "2035 Report."
[25] Edison Electric Institute, "Southern Company Driving Transportation Electrification," accessed July 26, 2021, https://www.eei.org/future/Pages/story.aspx?sid=14_Southern%20Company%20Driving%20Transportation%20Electrification.

alone.[26] It is no surprise, then, that retailers and shipping companies such as Amazon, UPS, and FedEx are beginning to electrify their fleets with electric semi-trucks, tractors, and vans.[27]

IMPLAN Jobs Modeling Results

In total, selected projects to reduce emissions and largely decarbonize major maritime port operations in the United States would support an average of nearly 32,000 jobs per year, many of them in the construction industry.[28] The projects addressed by this report involve spending of approximately $18.5 billion over 10 years.

Table 1: Summary of Employment Impacts

Impact	Employment Effects (total job years over 10 years)	Employment Effects (average per year)
1 - Direct	100,200	10,020
2 - Indirect	75,400	7,540
3 - Induced	141,100	14,100
4 - Total	**316,700**	**31,670**

The employment impacts are categorized as direct, indirect, and induced. "Direct" jobs are those created from the direct investment in the decarbonization activity, for example microgrid installation or energy efficiency retrofits on-site. The "indirect" jobs are those created along the supply chain, such as solar module or storage battery manufacturing. Induced jobs are those resulting from workers spending their income and have no direct relationship to the decarbonization activity.

This particular analysis does not account for "business-as-usual" activity; rather, it assumes that all investments to reduce emissions and decarbonize ports are additional, that all new demand for electricity at ports will be met by the new utility-scale solar PV and storage, and that all supply chain equipment and materials will be manufactured in the United States. Lastly, this is not a net-jobs study. Our model only predicts the jobs created through investments, and does not estimate the job losses in industries whose output would be displaced by electrification technologies.

[26] Josh Fisher, "Electric Last-Mile Delivery Could Save Industry $540M This Season," FleetOwner, November 30, 2017, https://www.fleetowner.com/news/economics/article/21701543/electric-lastmile-delivery-could-save-industry-540m-this-season.

[27] Sarah Steinberg, "Nevada Should Join the EV Fleet Bandwagon," accessed July 16, 2021, https://blog.aee.net/nevada-should-join-the-ev-fleet-bandwagon.

[28] The model estimates around 316,700 job-years over 10 years. Over a ten year period, this equals about 32,000 jobs per year.

Figure 1: Employment Effects (Job Years)

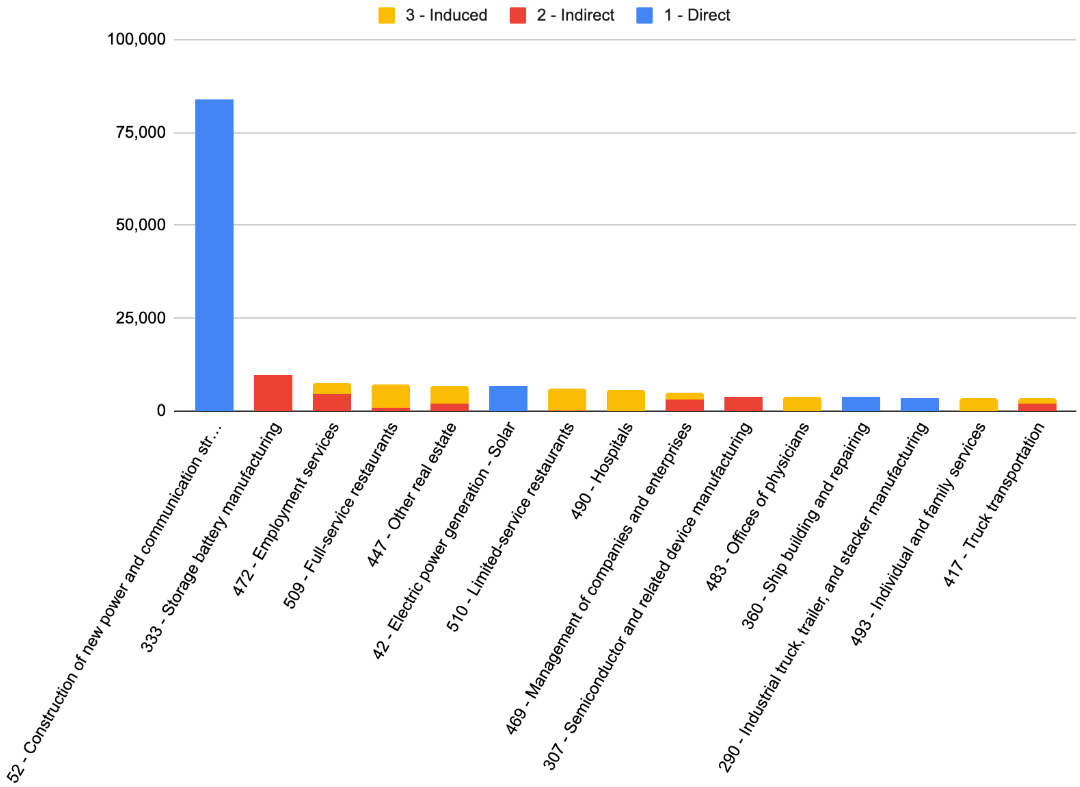


Figure 1 shows the 15 industries most positively affected by port decarbonization activities. The construction industry sees the greatest employment impact. The industry called "Construction of new power and communications structures" accounts for the following decarbonization activities: shoreside shore power, electric vehicle charging infrastructure, microgrids, and utility-scale solar PV and storage construction. Storage battery manufacturing is the second most impacted industry. This industry accounts for batteries in the following decarbonization activities: RTG cranes, cargo handling equipment, microgrids, tugboat and harbor-craft pilots, and utility-scale solar and storage. Solar module manufacturing is depicted in the semiconductor manufacturing sector. Operations and maintenance of solar and storage facilities to generate and deliver electricity is represented in the category "electric power generation - solar industry."

Tables 2 and 3 below show the direct employment impacts in the top five industries, and the indirect and induced employment effects of the top 10 industries, respectively.

Table 2: Top Five Industries - Direct Employment

Industry	Direct Employment Effects (total job years over 10 years)	Direct Employment Effects (average per year)
Construction of new power and communication structures	84,063	8,406
Electric power generation - Solar	6,721	672
Ship building and repairing	3,710	371
Industrial truck, trailer, and stacker manufacturing	3,618	362
Maintenance and repair construction of nonresidential structures	1,243	124
Total	**99,3565**	**9,936**

Table 3: Top 10 Industries - Indirect and Induced Employment

Industry	# Indirect + Induced Jobs (over 10 years)	# Indirect and Induced jobs (average per year)
Employment services	2,963	296
Full-service restaurants	1,536	1546
Other real estate	1,447	145
Electric power transmission and distribution	1,217	122
Limited-service restaurants	1,028	1037
Hospitals	979	98
Scenic and sightseeing transportation and support activities for transportation	778	78
Truck transportation	704	704
Offices of physicians	659	66
Other local government enterprises	604	60
Total	**11,913**	**1,1913**

The full IMPLAN output results are available at: Ocean Conservancy IMPLAN Results (FINAL) or upon request to the authors.

Scope

This report describes job creation from projects needed to charge electric drayage trucks, electrify cargo-handling equipment, supply shore power to ships in port, perform energy efficiency upgrades, install port microgrid systems, and supply renewable electricity to ports. These activities could be funded by federal or state infrastructure and economic recovery programs.

Ports in California have been making these kinds of investments for several years. The Port of Long Beach has already invested more than $185 million in shore power infrastructure, and the Port of Los Angeles has invested $7.7 million to install zero-emissions top handlers, with a goal of ensuring all their cargo-handling equipment are emissions-free by 2030.[29]

Drayage trucks serving maritime ports in the U.S. are particularly ripe for transition from diesel to electric drives. This transition can happen gradually as equipment ages out, but support for this transition needs to start now, particularly to plan and construct charging and electric power infrastructure, which will need to precede widespread retail purchase of heavy duty electric trucks. Ports and port tenants are often a key player in developing charging infrastructure. Some ports, including the Port of Oakland, own and operate the local electric distribution system and are the only ones who can make changes to that infrastructure. Others are critical partners to regional utilities, who can't proceed without port cooperation. Clearly not all drayage truck charging will occur within port boundaries, but at least some charging infrastructure will be needed at or near maritime port facilities.

Similarly, ports today rely almost exclusively on diesel powered cargo handling equipment (e.g., yard trucks, cranes, and rubber tired gantries). This equipment is also amenable to shifts toward electric drives and needs charging infrastructure to do so.

Shore power has been implemented quite successfully at ports in California, producing large economic and health benefits.[30] Other ports in the US could and should move to supply power to ships at berth so that ship engines can be turned off during loading and unloading operations.

Energy efficiency, particularly in regard to lighting systems, is a well established way to reduce facility costs and improve performance. Yet many US Maritime ports have not yet captured the benefits of more efficient port lighting.

Our study looked at jobs created by several pilot projects including microgrids and zero-emission tugboats. Microgrids have potential to provide back up power to ports, so that they can operate during electric grid emergencies such as power outages associated with wildfires or earthquakes in California. Pilots to test use of renewable hydrogen in harbor craft (e.g. tugboats) can both reduce emissions in the short term and gain experience with the hydrogen fuel cycle to seed larger emissions in the future.[31]

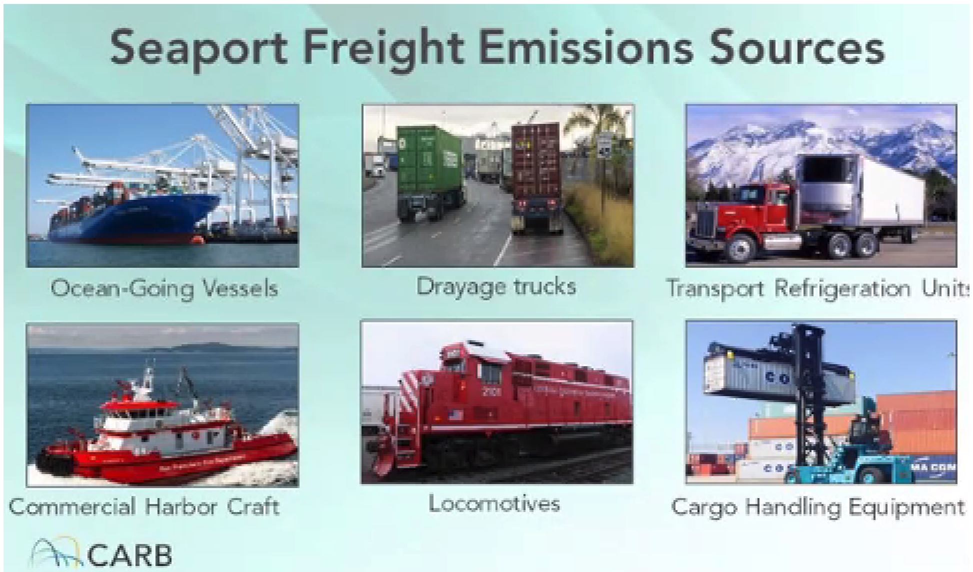
---

[29] Harry Saltzgaver, "Port of Long Beach Uses Electricity to Reach Zero Emissions Goal," Press Telegram, March 31, 2021,
https://www.presstelegram.com/2021/03/31/port-of-long-beach-uses-electricity-to-reach-zero-emissions-goal.

[30] Equipping ports with electric shore power capacity (also known as "cold ironing") to power ships while they are docked, instead of relying on their combustion-based engines, reduces air pollution associated with ships in port by 95%.

[31] Haskell, "How Ports Can Be the Catalyst for Shipping's Zero-Carbon Transition."

Figure 2: Seaport Freight Emissions Sources



Source: PowerPoint Presentation, California Air Resources Board, *Freight Days Meeting*, June 8, 2021.

This report primarily addresses electrification technologies, not port automation. Port automation has high upfront capital costs that would likely require a level of funding that is beyond the scope of current infrastructure and stimulus initiatives, typically involves significant disruption of port operations, can adversely affect port competitiveness, and can have negative employment impacts. A survey of global ports indicated that automation caused port productivity to fall by 7-15%. Port automation still faces many barriers that need addressing before warranting significant investments.[32]

Infrastructure Investment Categories

We estimated the costs of nine different categories of port infrastructure investments, totaling about $18.5 billion over 10 years. This figure is based on the list below, excluding the spending on electricity production which is a result of other spending categories, but is not likely to be supported by federal or state funding under port infrastructure packages.

These expenditures were the basis for employment modeling using the input-output model developed by IMPLAN:

1. **Shore Power ($2,717,000,000)**: cost of capital upgrades for berths and vessel retrofits to allow ships to turn off bunker-fueled engines while in port.
2. **Rubber Tired Gantry Crane (RTG) Electrification ($412,500,000)**: cost of retrofitting a portion of the existing fleet of diesel RTGs to all-electric or hybrid-electric, and the replacement of the

[32] Fox Chu et al., "The Future of Port Automation | McKinsey," accessed July 26, 2021, https://www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/the-future-of-automated-ports#.

remaining portion of the diesel RTG fleet with new fully electric RTGs (depending on age of equipment and other considerations).

3. **Cargo Handling Equipment Electrification ($2,974,000,000):** includes the cost of replacing diesel-powered equipment (e.g., yard trucks, forklifts, top handlers, side picks, and straddle carriers) with all-electric models.
4. **Drayage Truck Electrification ($558,000,000):** cost of installing DC fast chargers and workplace level 2 chargers; does not include the cost of electric trucks themselves.
5. **Energy Efficiency Upgrades ($280,000,000):** cost of upgrading to more efficient lighting systems at ports.
6. **Port Microgrid Pilots ($500,000,000):** cost of installing solar and battery storage microgrid systems to increase resiliency to grid emergencies and to optimize power purchases from grid.
7. **Tugboat Decarbonization Pilot ($500,000,000):** cost of running a limited number of pilot projects at the largest ports.
8. **Solar PV + Storage Electricity Generation Capacity ($10,563,000,000):** capital cost of building out electricity generation capacity from all-renewable resources to meet increased demand in electricity resulting from port electrification investments.
9. **Increased Electricity Production and Delivery ($7,423,300,000):** increased electricity sales to supply electric drayage trucks, electric cargo handling equipment, and shore power over 10 years.

Methodology

The IMPLAN model is an input-output (I-O) model based on federal government data. This model was used to estimate the employment impacts associated with specific port decarbonization activities. I-O modeling is typically used to analyze how a change in economic activity in one sector of the economy affects that sector as well as activities, employment, and labor income in other sectors of the economy. IMPLAN is not dynamic, which means that it does not account for any feedback, such as price adjustments or business, worker, and consumer activity adjustments in response to changing prices.

The IMPLAN model has 546 industry sectors for which it maps upstream and downstream relationships with other industry sectors. When you model an impact to a particular industry, it uses preset industry spending patterns to discern the indirect and induced effects resulting from the initial impact. Even with 546 industry sectors, there are often decarbonization and clean energy activities with spending patterns that differ substantially from the closest match in IMPLAN. When this is the case, IMPLAN allows the user to customize the industry spending patterns in an “analysis-by-parts”. Researchers attempting to develop more accurate or specific impacts related to decarbonization activities can distribute intermediate expenditures to industries that better reflect the supply chain differences between, for example, diesel and electric cargo moving equipment or generic electricity infrastructure and microgrids. Such an “analysis-by-parts” methodology was used in this study.

To do this, we reviewed literature on cost breakdowns for each of the port decarbonization activities and then made adjustments to the industry spending patterns for those industries. The most significant of these were for those activities requiring storage batteries or solar panels.

IMPLAN also allows the user to specify the percent of local demand met by local suppliers. This analysis assumes 100% local content, assembly, and other services, reflective of a "Buy America" provision tied to federal port decarbonization investments.[33] Because we modeled effects across the entire United States, the 100% local production assumption led to about 10% more jobs than would have been created otherwise.

Key Modeling Assumptions and Exclusions

This study makes a few key assumptions:

- Investment would occur over a 10-year period.
- Any purchases would be subject to a "Buy America" condition for components.
- Estimates relate to infrastructure investments required at the largest ports in the United States (e.g. container ports), not ports with small cargo and freight throughput.
- Electricity supply to meet increased power consumption from equipment electrification will be met by new utility-scale solar and storage capacity.

This study addresses a subset of potential infrastructure improvements to reduce emissions from maritime ports. We do not attempt to estimate job production from a wider range of projects that would be needed to achieve zero emission port operations. Not included in this report are the following:

- Technology and fuel shifts needed to reduce or eliminate emissions from ocean-going ships before arrival at port berths and after departure.
- Conversion of entire harbor craft and tugboat fleets to battery electric or hydrogen fuel cell propulsion (including hydrogen fueling infrastructure). We do include costs and jobs for a limited number of harbor craft and tugboat zero emission pilot projects.

We chose to exclude the latter for several reasons. First, while renewable hydrogen (RH2) costs have dropped over the past five years and will continue to decline, prices and RH2 fueling infrastructure are not yet at a level that would make widespread harbor craft conversion feasible. Batteries may be feasible for certain types of harbor craft (e.g., smaller ferries), but not yet for the higher emitting vessels (tugboats). Additionally, fleets would likely not be converted at once, but rather spread out over a period of 20 years. Notably, no zero emission tugboats have been constructed for container port use so far, so there is insufficient experience with the technology. Lastly, the technology is, at this time, very

[33] Andrea Shalal, "Biden Promotes Tougher 'Buy American' Rules in Visit to Mack Trucks Plant," Reuters, July 28, 2021,
https://www.reuters.com/world/us/biden-tout-tougher-buy-american-rules-visit-mack-trucks-plant-2021-07-28/?eType=EmailBlastContent&eId=d3084dbc-2c8c-4296-b612-af6e25e88e04.

expensive. Wingrove (2016) estimates that an average hydrogen-based tugboat would cost $25 million. With a fleet of about 1,700 vessels, that would cost around $42.5 billion.[34,35] This upfront cost would likely not be feasible at this moment in time.

In some cases we used conservative assumptions to avoid over-estimating jobs produced by port electrification. For example, we do not include jobs associated with manufacturing electric drayage trucks, as those jobs will likely replace existing jobs in truck manufacturing. By contrast, we do include jobs associated with manufacturing of cargo handling equipment since new forms of funding would likely accelerate replacement of existing equipment.

Finally, this is not a net-jobs study. Our model only predicts the jobs created through investments, and does not estimate the job losses in industries whose output would be displaced by electrification technologies.

Background research

Technologies, cost estimates and port data were informed by online research and drawn from published journal articles, government agency reports, and publicly available documents released by US ports. Estimated costs were drawn from examples in California, where ports have already implemented numerous electrification projects.

For shore power, we found that, on average, capital costs for electrifying a single berth hovered around $4 million in total, and retrofitting vessels for shore power cost about $174 per TEU. [36,37,38]

Data for electric cargo handling equipment (CHE) costs mostly came from reports from the Ports of Oakland, Los Angeles and Long Beach, which provided detailed costs of each piece of equipment. We found that retrofits of rubber tired gantry cranes (RTGs) cost about $500,000, whereas new all-electric RTGs cost around $2.15 million, or about $150,000 more than a new diesel RTG.[39] Electric yard trucks

---

[34] Martyn Wingrove, "US Operates Second-Largest Tugboat Fleet," Riviera, accessed July 20, 2021, https://www.rivieramm.com/news-content-hub/news-content-hub/us-operates-second-largest-tugboat-fleet-30608.

[35] Joseph Pratt and Leonard Klebanoff, "Feasibility of the SF-BREEZE: A Zero-Emission, Hydrogen Fuel Cell, High-Speed Passenger Ferry" (Sandia National Laboratories, September 2016).

[36] ENVIRON International Corporation, "Cold Ironing Cost Effectiveness Study" (Port of Long Beach, March 30, 2004), http://www.lbreport.com/port/coldiron.pdf.

[37] Haifeng Wang, Xiaoli Mao, and Dan Rutherford, "Costs and Benefits of Shore Power at the Port of Shenzhen" (The International Council on Clean Transportation, December 28, 2015).

[38] California Air Resources Board, "Appendix B: Proposed Control Measure for Ocean-Going Vessels Operating at Berth; Cost Analysis for Standardized Regulatory Impact Assessment," August 1, 2019, https://ww3.arb.ca.gov/regact/2019/ogvatberth2019/appb.pdf.

[39] AECOM, "Zero-Emission Cargo-Handling Equipment Feasibility Assessment" (Port of Oakland, November 21, 2019), https://www.portofoakland.com/files/PDF/AECOM%20Zero%20emission%20CHE%20feasibility%20assessment%20Nov%202019.pdf.

currently cost about $250,000 each, forklifts at $45,000, top handlers and side picks at $1.6 million, and straddle carriers at $2.5 million.[40]

For drayage truck electrification, we focused on port-side infrastructure (and not the cost of trucks themselves) and found that DC fast chargers cost about $81,000 each, whereas workplace level 2 chargers had a much lower price point of $4,000 each.[41,42,43,44]

For microgrid systems (onsite renewable energy and battery storage), which have mostly been installed in southern California, we estimated the costs to be about $10 million per system.[45,46]

Tugboat decarbonization pilots rely mostly on Sandia National Laboratory findings, which estimated costs to be around $25 million per pilot project.[47]

Lastly, our estimates of electricity demand increase from electrification of cargo handling equipment and shore power draw primarily from a Department of Transportation Study, which estimated the approximate energy consumption in kWh/TEU for four different ports in the U.S. This study found an average of 57.67 kWh/TEU for cargo handling equipment and 51.25 kWh/TEU for shore power.[48] For

---

[40] EnSafe Inc., "Preliminary Cost Estimates for Select Clean Air Action Plan Strategies" (Port of Long Beach and Port of Los Angeles, November 2017), http://www.cleanairactionplan.org/wp-content/uploads/2017/10/a448a54258909bb3022b731890e70794.pdf.

[41] Michael Nicholas, "Estimating Electric Vehicle Charging Infrastructure Costs across Major U.S. Metropolitan Areas" (International Council on Clean Transportation, August 2019), https://theicct.org/sites/default/files/publications/ICCT_EV_Charging_Cost_20190813.pdf.

[42] RMI, BAAQMD, and ICCT provide ranges for Level 2 overnight chargers at $2,500-$6,500 per charger. We used an average cost of $4,000 for an overnight charger.

[43] Chris Nelder and Emily Rogers, "Reducing EV Charging Infrastructure Costs" (Rocky Mountain Institute, 2019), https://rmi.org/insight/reducing-ev-charging-infrastructure-costs/.

[44] Gladstein, Neandross & Associates, "Electric Vehicle Charging Guidebook for Medium- and Heavy-Duty Commercial Fleets," 2019, https://www.gladstein.org/gna_whitepapers/electric-vehicle-charging-guidebook-for-medium-and-heavy-duty-commercial-fleets/.

[45] Alexander Nguyen, "Port of San Diego Receives Grant Funding for Microgrid Installation," Times of San Diego, June 20, 2018, https://timesofsandiego.com/politics/2018/06/19/port-of-san-diego-receives-grant-funding-for-microgrid-installation/.

[46] Note, the cost of microgrid installation was $9.6 million total, but we subtracted out $2 million in warehouse upgrade costs, resulting in $7.5 million for a 700 kW installation; scaled up to 1 MW, an installation would cost around $10 million

[47] Pratt and Klebanoff, "Feasibility of the SF-BREEZE: A Zero-Emission, Hydrogen Fuel Cell, High-Speed Passenger Ferry."

[48] Ellen Schenk et al., "Macroeconomic And Environmental Impacts of Port Electrification: Four Port Case Studies" (U.S. Maritime Administration, Department of Transportation, August 2020), https://www.maritime.dot.gov/sites/marad.dot.gov/files/2020-09/Port%20Electrification%20MARAD%20Final%20Report.pdf.

drayage truck electricity demand, we used a study from the University of California, Los Angeles on zero-emission drayage trucks, which found a monthly consumption of 11,486 kWh.[49]

Conclusion

Maritime port operations emit large amounts of toxic air pollution and greenhouse gases. The former are of particular concern to low income communities of color near port facilities and related freeways and transit ups. It does not have to be that way. There are many opportunities to reduce air pollution from diesel powered equipment, using available electric drive technology. Energy efficiency and microgrid projects can also help reduce costs, reduce air pollution, and increase port resilience to grid and weather emergencies. Renewable hydrogen production, storage and fueling infrastructure pilots offer real-world experiences with a new energy source that will eventually be needed for ships and harbor craft.

Federal funding of approximately $18.5 billion for these projects would help overcome a variety of financial and market barriers to achieve low carbon and community-safe operations. These expenditures can create approximately 32,000 jobs over a 10 year period which will help secure economic recovery from the COVID-19 epidemic.

For further information contact:

David Wooley, Executive Director & Lecturer
Center for Environmental Public Policy
Goldman School of Public Policy
University of California, Berkeley
dwooley@berkeley.edu
415-271-1135

[49] James Di Filippo, Colleen Callahan, and Naseem Golestani, “Zero-Emission Drayage Trucks: Challenges and Opportunities for the San Pedro Bay Ports” (UCLA Luskin Center for Innovation, October 2019), https://innovation.luskin.ucla.edu/wp-content/uploads/2019/08/Zero-Emission_Drayage_Trucks.pdf.

References

AECOM. “Zero-Emission Cargo-Handling Equipment Feasibility Assessment.” Port of Oakland, November 21, 2019. https://www.portofoakland.com/files/PDF/AECOM%20Zero%20emission%20CHE%20feasibility%20assessment%20Nov%202019.pdf.

Allen, Paul, Dana Lowell, Luke Hellgren, Jane Culkin, Dave Seamonds, and Grace Van Horn. “Newark Community Impacts of Mobile Source Emissions.” M.J. Bradley & Associates, November 2020.

Apte, Joshua, Kyle Messier, Shahzad Gani, Michael Brauer, Thomas Kirchstetter, Melissa Lunden, Julian Marshall, Christopher Portier, Roel Vermeulen, and Steven Hamburg. “High-Resolution Air Pollution Mapping with Google Street View Cars: Exploiting Big Data.” *Environmental Science & Technology* 51, no. 12 (June 5, 2017): 6999–7008.

California Air Resources Board. “Advanced Clean Trucks Total Cost of Ownership Discussion Document - Preliminary Draft for Comment,” February 22, 2019.

California Air Resources Board. “Appendix B: Proposed Control Measure for Ocean-Going Vessels Operating at Berth; Cost Analysis for Standardized Regulatory Impact Assessment,” August 1, 2019. https://ww3.arb.ca.gov/regact/2019/ogvatberth2019/appb.pdf.

California Air Resources Board. “Emission Reduction Plan for Ports and Goods Movement in California,” April 20, 2006.

California Air Resources Board. “Summary: Diesel Particulate Matter Health Impacts.” Accessed July 28, 2021. https://ww2.arb.ca.gov/resources/summary-diesel-particulate-matter-health-impacts.

Chu, Fox, Sven Gailus, Lisa Liu, and Liumin Ni. “The Future of Port Automation | McKinsey.” Accessed July 26, 2021. https://www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/the-future-of-automated-ports#.

Di Filippo, James, Colleen Callahan, and Naseem Golestani. “Zero-Emission Drayage Trucks: Challenges and Opportunities for the San Pedro Bay Ports.” UCLA Luskin Center for Innovation, October 2019. https://innovation.luskin.ucla.edu/wp-content/uploads/2019/08/Zero-Emission_Drayage_Trucks.pdf.

Edison Electric Institute. “Southern Company Driving Transportation Electrification.” Accessed July 26, 2021. https://www.eei.org/future/Pages/story.aspx?sid=14_Southern%20Company%20Driving%20Transportation%20Electrification.

EnSafe Inc. “Preliminary Cost Estimates for Select Clean Air Action Plan Strategies.” Port of Long Beach and Port of Los Angeles, November 2017. http://www.cleanairactionplan.org/wp-content/uploads/2017/10/a448a54258909bb3022b731890e70794.pdf.

ENVIRON International Corporation. “Cold Ironing Cost Effectiveness Study.” Port of Long Beach, March 30, 2004. http://www.lbreport.com/port/coldiron.pdf.

Environmental Defense Fund. “How Pollution Impacts Health in West Oakland.” Accessed July 28, 2021. https://www.edf.org/airqualitymaps/oakland/pollution-and-health-concerns-west-oakland.

Fisher, Josh. “Electric Last-Mile Delivery Could Save Industry $540M This Season.” FleetOwner, November 30, 2017. https://www.fleetowner.com/news/economics/article/21701543/electric-lastmile-delivery-could-save-industry-540m-this-season.

Gladstein, Neandross & Associates. “Electric Vehicle Charging Guidebook for Medium- and Heavy-Duty Commercial Fleets,” 2019.

https://www.gladstein.org/gna_whitepapers/electric-vehicle-charging-guidebook-for-medium-and-heavy-duty-commercial-fleets/.

Haskell, Charles. “How Ports Can Be the Catalyst for Shipping’s Zero-Carbon Transition.” *Lloyd’s Register Horizons*, July 2021.

Houston, Douglas, Margaret Krudysz, and Arthur Winer. “Diesel Truck Traffic in Low-Income and Minority Communities Adjacent to Ports.” *Transportation Research Record: Journal of the Transportation Board Research*, December 1, 2008. https://doi.org/10.3141/2067-05.

Leung, Jessica, and Janet Peace. “Insights On Electric Trucks For Retailers And Trucking Companies.” Center for Climate and Energy Solutions, February 2020.

Marquez, Jesse N. “Importing Harm: U.S. Ports’ Impacts on Health and Communities.” THE Impact Project, January 2012. http://envhealthcenters.usc.edu/wp-content/uploads/2016/11/Impact-Project-Ports-issue-brief-2012-1.pdf.

Michael Nicholas. “Estimating Electric Vehicle Charging Infrastructure Costs across Major U.S. Metropolitan Areas.” International Council on Clean Transportation, August 2019. https://theicct.org/sites/default/files/publications/ICCT_EV_Charging_Cost_20190813.pdf.

Morello-Frosch, Rachel, Manuel Pastor, and James Sadd. “Environmental Justice and Southern California’s ‘Riskscape’: The Distribution of Air Toxics Exposures and Health Risks among Diverse Communities.” *Urban Affairs Review* 36, no. 4 (March 1, 2001): 551–78.

Nelder, Chris, and Emily Rogers. “Reducing EV Charging Infrastructure Costs.” Rocky Mountain Institute, 2019. https://rmi.org/insight/reducing-ev-charging-infrastructure-costs/.

Nguyen, Alexander. “Port of San Diego Receives Grant Funding for Microgrid Installation.” Times of San Diego, June 20, 2018. https://timesofsandiego.com/politics/2018/06/19/port-of-san-diego-receives-grant-funding-for-microgrid-installation/.

Office of Air and Radiation, US EPA. “Environmental Justice Primer for Ports: Impacts of Port Operations and Goods Movement.” Overviews and Factsheets, July 31, 2019. https://www.epa.gov/community-port-collaboration/environmental-justice-primer-ports-impacts-port-operations-and-goods.

Office of Air and Radiation, US EPA. “Ports Primer: 2.1 The Role of Ports.” Overviews and Factsheets, September 18, 2016. https://beta.epa.gov/community-port-collaboration/ports-primer-21-role-ports.

Office of Transportation Air Quality, US Environmental Protection Agency. “National Port Strategy Assessment: Reducing Air Pollution and Greenhouse Gases at U.S. Ports,” September 2016. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100PGK9.pdf.

Perez, Laura, Nino Künzli, Ed Avol, Andrea Hricko, Fred Lurmann, Elisa Nicholas, Frank Gilliland, John Peters, and Rob McConnell. “Global Goods Movement and the Local Burden of Childhood Asthma in Southern California.” *American Journal of Public Health* 99 (March 10, 2009).

Phadke, Amol, Nikit Abhyankar, Jessica Kersey, Taylor McNair, Umed Paliwal, David Wooley, Olivia Ashmoore, et al. “2035 Report.” Goldman School of Public Policy, April 15, 2021. https://www.2035report.com/transportation/downloads/.

Phadke, Amol, Aditya Khandekar, Nikit Abhyankar, David Wooley, and Deepak Rajagopal. “Why Regional and Long-Haul Trucks Are Primed for Electrification Now.” Lawrence Berkeley National Laboratory, March 2021. https://eta-publications.lbl.gov/sites/default/files/updated_5_final_ehdv_report_033121.pdf.

Pratt, Joseph, and Leonard Klebanoff. “Feasibility of the SF-BREEZE: A Zero-Emission, Hydrogen Fuel Cell, High-Speed Passenger Ferry.” Sandia National Laboratories, September 2016.

Saltzgaver, Harry. “Port of Long Beach Uses Electricity to Reach Zero Emissions Goal.” Press Telegram, March 31, 2021. https://www.presstelegram.com/2021/03/31/port-of-long-beach-uses-electricity-to-reach-zero-emissions-goal.

Schenk, Ellen, Edward Carr, James J. Corbett, and James J. Winebrake. “Macroeconomic And Environmental Impacts of Port Electrification: Four Port Case Studies.” U.S. Maritime Administration, Department of Transportation, August 2020. https://www.maritime.dot.gov/sites/marad.dot.gov/files/2020-09/Port%20Electrification%20MARAD%20Final%20Report.pdf.

Shalal, Andrea. “Biden Promotes Tougher ‘Buy American’ Rules in Visit to Mack Trucks Plant.” Reuters, July 28, 2021. https://www.reuters.com/world/us/biden-tout-tougher-buy-american-rules-visit-mack-trucks-plant-2021-07-28/?eType=EmailBlastContent&eId=d3084dbc-2c8c-4296-b612-af6e25e88e04.

Steinberg, Sarah. “Nevada Should Join the EV Fleet Bandwagon.” Accessed July 16, 2021. https://blog.aee.net/nevada-should-join-the-ev-fleet-bandwagon.

Wang, Haifeng, Xiaoli Mao, and Dan Rutherford. “Costs and Benefits of Shore Power at the Port of Shenzhen.” The International Council on Clean Transportation, December 28, 2015.

Wingrove, Martyn. “US Operates Second-Largest Tugboat Fleet.” Riviera. Accessed July 20, 2021. https://www.rivieramm.com/news-content-hub/news-content-hub/us-operates-second-largest-tugboat-fleet-30608.

Wu, Xiao, Rachel C. Nethery, Benjamin M. Sabath, Danielle Braun, and Francesca Dominici. “Fine Particulate Matter and COVID-19 Mortality in the United States.” *Science Advances* 6, no. 45 (November 4, 2020). https://projects.iq.harvard.edu/covid-pm/home.