ATTACHMENT 1 - BENEFIT COST ANALYSIS

Approach

The benefit-cost analysis adapts a conventional, conservative approach, as indicated in the DOT Guidelines. Detailed calculations are presented in the spreadsheets at the end of this Attachment.

Costs. Project costs for the project have each been segmented into Lands and Easements, Design and Procurement, Construction (including mobilization, construction management/inspections, site work, and demolition), Equipment, and Maintenance with a Contingency allowance shown separately.

Benefits. The benefits associated with the two project components include:

1. **GHG and Criteria Pollutant Emissions** – Reduction in emissions of GHGs and criteria pollutants through increased use battery-electric drayage and yard tractors, and increased use of shore power ("cold-ironing") instead of vessel auxiliaries in port.
2. **Health Benefits from Renewable Power** - Producing energy from renewable sources reduces the air pollution and other health burdens associated with fossil-fuel-based electrical power.
3. **Reductions in Operating Expenses** - Reduction in maintenance and downtime expenses associated with use of more reliable electrically-powered equipment and reduction in fuel cost due to more efficient engines (not quantified).
4. **Resilience** – Reductions in lost labor productivity due to power loss or limitation, and reduction in losses of refrigerated and frozen cargoes (not quantified).
5. **Safety** - Reduction in accident risk through replacement of end-of-life electrical infrastructure (not quantified).

These categories are closely related but have been defined and estimated to be additive and cumulative, rather than overlapping.

In each case, the quantified benefits consist of tangible cost savings, including the monetized equivalent of emissions savings and health benefits, and do not include diversion from competing ports or other shifts that could be considered transfers. The benefits will likely be distributed among exporters, importers, terminal operators, ocean carriers, drayage companies, the West Oakland community, the Port of Oakland, and other industry participants.

The primary sources for the benefit-cost analysis include:

- Project cost information provided by Port staff
- Port of Oakland records of electric drayage charging and power usage
- PIDP Program guidance: *Notice of Funding Opportunity for the Maritime Administration's Port Infrastructure*
- *Development Program (PIDP) under the Consolidated Appropriations Act, 2021*
- US DOT: *Benefit Cost Analysis Guidance for Discretionary Grant Programs*, February 2021
- US EPA: *Public Health Benefits per kWh of Energy Efficiency and Renewable Energy in the United States: A Technical Report*, May 2021
- US EPA: *DrayFleet Drayage Emissions and Cost Model*, https://nepis.epa.gov/Exe/ZyNET.exe/P100FE3O.TXT?ZyActionD=ZyDocument&Client=EPA&Ind

ex=2011+Thru+2015&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C11thru15%5CTxt%5C00000006%5CP100FE3O.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL

- US National Renewable Energy Laboratory, PVWatts calculator, https://pvwatts.nrel.gov/pvwatts.php

Wherever possible, the analysis uses Activity-Based Costing to develop a clear picture of how benefits are generated and how their value has been estimated.

Project Costs

Project cost estimates are summarized in Table 1 and shown in detail in Table 2. The proposed substation replacement is a high-priority project for the Port, and scoping for the design is expected to start in August 2021. Design will begin in late Calendar Year (CY) 2021, and will be completed in June 2022. Required environmental approvals are also expected to be completed in June 2022, or earlier (the only required environmental approval not currently in hand is NEPA review). As explained in the Project Narrative NEPA review is expected to consist of an EA. Grants funds would be obligated no later than June 2022, and contracting for construction would begin immediately. Design costs would not be eligible for grant funding.

Table 1: Project Cost Summary

Project Costs	Present Value
Capital Cost	$ 17,392,700
Maintenance Cost	$ 267,794
Operating Cost	$ 1,286,856
Total Present Value	**$ 18,947,350**

Because the Port is a public utility, it does not require any approvals to construct or upgrade infrastructure. This opportunity is unique among major U.S. container ports, and provides an exceptionally clear path from design through construction. Utility (Pacific Gas and Electric Company, PG&E) review and an interconnection agreement are required to interconnect the substation to PGE's transmission grid. The utility reviews will begin by November 2021, and are scheduled to be completed within 18 months, running concurrent with design and construction. Negotiations on the interconnection agreement would begin approximately 6 months after the start of the reviews, and are expected to conclude by September 2023, shortly before substation construction and commissioning are completed. Construction would begin in 1Q2023, and be completed in 3Q2024. Construction of the new substation and the solar array and storage would be completed in October 2023. Circuit 2 would be completed in July 2023 and the fuel cell in August 2023. The connection to the EBMUD generator would follow construction of Circuit 2, and be completed in June of 2024.

Table 2 also provides maintenance and operating costs. Maintenance costs include routine annual maintenance as well as regular major maintenance for the substation. Operating costs include the fuel for the substation (which is off-set by electricity sales), and rent for the warehouse roof that will host the solar array. Table 2 shows the total cost in current dollars and in Present Value (constant dollars) using the specified 7% discount rate. The estimated Present Value (PV) of project costs, including ongoing maintenance, is **$ $18,947,350**.

Table 2: Project Costs

Component	Activity	2021	2022	2023	2024	2025	2030	2035	2040	2045	2050	2052
Substation Replacement												
	Land, structures, rights-of-way, appraisals, etc.	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Design, including Admin and Legal	$55,000	$165,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Construction, including pre-construction submittals, site work, inspections and demolition	$0	$0	$2,950,000	$0	$0	$0	$0	$0	$0	$0	$0
	Equipment	$0	$0	$3,000,000	$0	$0	$0	$0	$0	$0	$0	$0
	Contingencies	$25,000	$75,000	$500,000	$0	$0	$0	$0	$0	$0	$0	$0
	TOTAL CAPITAL COST	**$80,000**	**$240,000**	**$6,450,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	Maintenance Cost-Substation Only	$0	$0	$0	$2,000	$2,000	$2,000	$5,000	$2,000	$2,000	$5,000	$2,000
	Annual Total	$80,000	$240,000	$6,450,000	$2,000	$2,000	$2,000	$5,000	$2,000	$2,000	$5,000	$2,000
	PV at 7% Discount Rate	$80,000	$224,299	$5,633,680	$1,633	$1,526	$1,088	$1,939	$553	$394	$703	$246
Circuit 2												
	Land, structures, rights-of-way, appraisals, etc.	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Design, including Admin and Legal	$55,000	$215,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Construction, including pre-construction submittals, site work, inspections and demolition	$0	$0	$1,875,000	$0	$0	$0	$0	$0	$0	$0	$0
	Equipment	$0	$0	$500,000	$0	$0	$0	$0	$0	$0	$0	$0
	Contingencies	$15,000	$60,000	$200,000	$0	$0	$0	$0	$0	$0	$0	$0
	TOTAL CAPITAL COST	**$70,000**	**$275,000**	**$2,575,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	Enhanced Maintenance (includes all other components except substation)	$0	$0	$0	$6,000	$6,000	$6,000	$12,000	$6,000	$6,000	$12,000	$6,000
	Annual Total	$70,000	$275,000	$2,575,000	$6,000	$6,000	$6,000	$12,000	$6,000	$6,000	$12,000	$6,000
	PV at 7% Discount Rate	$70,000	$257,009	$2,249,105	$4,898	$4,577	$3,264	$4,654	$1,659	$1,183	$1,687	$737
Fuel Cell												
	Land, structures, rights-of-way, appraisals, etc.	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Design, including Admin and Legal	$0	$95,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Construction, including pre-construction submittals, site work, inspections and demolition	$0	$0	$670,000	$0	$0	$0	$0	$0	$0	$0	$0
	Equipment	$0	$0	$1,000,000	$0	$0	$0	$0	$0	$0	$0	$0
	Contingencies	$0	$25,000	$25,000	$0	$0	$0	$0	$0	$0	$0	$0
	TOTAL CAPITAL COST	**$0**	**$120,000**	**$1,695,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	Maintenance	$0	$0	$0	$0	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000
	Operating Cost (Note: fuel and labor cost off-set by sale of electricity)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Annual Total	$0	$120,000	$1,695,000	$0	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000
	PV at 7% Discount Rate	$0	$112,150	$1,480,479	$0	$7,629	$5,439	$3,878	$2,765	$1,971	$1,406	$1,228
Solar Generation and Storage												
	Land, structures, rights-of-way, appraisals, etc.	$0	$0	$120,000	$0	$0	$0	$0	$0	$0	$0	$0
	Design, including Admin and Legal	$0	$420,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Construction, including pre-construction submittals, site work, inspections and demolition	$0	$0	$310,000	$0	$0	$0	$0	$0	$0	$0	$0
	Equipment	$0	$0	$4,000,000	$0	$0	$0	$0	$0	$0	$0	$0
	Contingencies	$0	$25,000	$25,000	$0	$0	$0	$0	$0	$0	$0	$0
	TOTAL CAPITAL COST	**$0**	**$445,000**	**$4,455,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	Maintenance	$0	$0	$0	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
	Operating Cost (roof rental)	$0	$0	$0	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000
	Annual Total	$0	$445,000	$4,455,000	$125,000	$125,000	$125,000	$125,000	$125,000	$125,000	$125,000	$125,000
	PV at 7% Discount Rate	$0	$415,888	$3,891,170	$102,037	$95,362	$67,992	$48,477	$34,564	$24,643	$17,570	$15,347
Direct Connection to EBMUD Generator												
	Land, structures, rights-of-way, appraisals, etc.	$0	$200,000	$50,000	$0	$0	$0	$0	$0	$0	$0	$0
	Design, including Admin and Legal	$0	$450,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Construction, including pre-construction submittals, site work, inspections and demolition	$0	$0	$1,075,000	$1,000,000	$0	$0	$0	$0	$0	$0	$0
	Equipment	$0	$0	$250,000	$250,000	$0	$0	$0	$0	$0	$0	$0
	Contingencies	$0	$25,000	$75,000	$75,000	$0	$0	$0	$0	$0	$0	$0
	TOTAL CAPITAL COST	**$0**	**$675,000**	**$1,450,000**	**$1,325,000**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	Operating Cost (included in Substation Maintenance)	$0	$0	$0	$0		$0	$0	$0	$0	$0	$0
	Annual Total	$0	$675,000	$1,450,000	$1,325,000	$0	$0	$0	$0	$0	$0	$0
	PV at 7% Discount Rate	$0	$630,841	$1,266,486	$1,081,595	$0	$0	$0	$0	$0	$0	$0
Total Cost												
	Capital Cost	$150,000	$1,755,000	$16,625,000	$1,325,000	$0	$0	$0	$0	$0	$0	$0
	Capital Cost PV	$150,000	$1,640,187	$14,520,919	$1,081,595	$0	$0	$0	$0	$0	$0	$0
	Maintenance Cost	$0	$0	$0	$13,000	$23,000	$23,000	$32,000	$23,000	$23,000	$32,000	$23,000
	Maintance Cost PV	$0	$0	$0	$10,612	$17,547	$12,510	$12,410	$6,360	$4,534	$4,498	$2,824
	Operating Cost	$0	$0	$0	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000
	Operating Cost PV Total	$0	$0	$0	$97,956	$91,547	$65,272	$46,538	$33,181	$23,658	$16,868	$14,733
	Annual Total	$150,000	$1,755,000	$16,625,000	$1,458,000	$143,000	$143,000	$152,000	$143,000	$143,000	$152,000	$143,000
	Total Annual PV	$150,000	$1,640,187	$14,520,919	$1,190,162	$109,094	$77,783	$58,948	$39,541	$28,192	$21,366	$17,557
	Project Cost PV Total	**$ 18,947,350**										

Project Benefits

Emissions Reduction Benefits

The substation project will enable the Port to provide adequate, reliable electric power for three critical applications:

- Charging electric drayage and yard tractors that will replace diesel units.
- Supplying electrical shorepower to replace the use of diesel auxiliary engines on berthed assist tugs.
- Supply electrical shorepower to replace the use of legacy diesel auxiliary engines on U.S. Navy vessels layberthed at Oakland's Outer Harbor.

Yard tractors. Diesel yard tractors ("hostlers") are used to move containers on chassis and bare chassis within marine container terminals. As of 2017 there were 105 terminal yard tractors active at the Port of Oakland and 120 additional on-road yard tractors. The terminal yard tractors operated an average of about 1,250 hours annually in short-trip, stop-start service that produces relatively high emissions. In 2017, terminal yard tractors emitted an estimated annual average per tractor of 0.199 metric tons (mtons) of NO_X, 0.004 mtons of $PM_{2.5}$, and 62.216 mtons of CO_2 (based on the Port's emissions inventory[i]). These tractors used an estimated average of 4,155 gallons of diesel fuel annually, the equivalent of 424 kWh of electrical power daily, requiring 14 hours at a 30 kwh charger (Table 3).

The industry has begin to deploy electric yard tractors at Oakland (right), but is limited by the available substation capacity and reliability. The Port of Oakland emissions benefits model for the project allows for 12 chargers to support 16 terminal yard tractors at Outer Harbor terminals.

Table 3: Yard Tractor Inputs

Yard Tractors	
Annual Diesel Gallon/Yard Tr	4,155
Daily kWh/Yard Tractor	424
Daily Charging Hours/Yard Tra	14
Yard Tractors/Charger	1.4

Drayage tractors. Drayage tractors move containers on chassis or bare chassis over public roads between marine container terminals and importers, exporters, rail terminals, and container depots. Drayage trips can range from less than a mile to port-area destinations, to hundreds of miles to inland cities. This analysis conservatively assumes that the electric drayage tractors introduced in the near future will be used at or near the port to avoid range issues on longer trips and to use power from the substation project.

[i] https://www.portofoakland.com/files/PDF/Port_Oakland_2017_Emissions_Inventory.pdf

The emissions estimates use the DrayFleet drayage emissions and cost model[ii] developed for the EPA SmartWay program and specifically designed to identify emissions and cost impacts of operational and technology changes in port drayage. The DrayFleet model was calibrated to the Port of Oakland's container volume and geography, as shown in Table 4.

Table 4: DrayFleet Model Parameters

Category	Value
Annual Activity	
Number of Drayage Trip Legs	3,102,324
Drayage Trip Legs per Container	2.2
Total Drayage VMT	26,688,617
Drayage VMT per Container	18.7
Fleet Required (FTE Tractors)	1,565
Annual Duty Cycle Totals	
Idle/Stopped Hours	3,026,062
Creep Hours	681,612
Transient Hours	264,497
Cruise Hours	555,058
Total Drayage Hours	4,527,229
Drayage Hours per Container	3.2

As shown in

Table 5, the DrayFleet model estimated that drayage tractors operating close to the Port use an average of 7,455 gallons of diesel fuel annually. Significantly, 2,036 gallons of diesel would be used while idling when electric vehicles would be using little or no power at all. DrayFleet yielded estimated annual emissions of 0.044 mtons of NO_X, 0.002 mtons of $PM_{2.5}$, and 69.788 mtons of CO_2 annually per tractor.

Table 5: DrayFleet Model Outputs

Model Outputs	Per Tractor
Pollutant (annual mtons)	
NOx	0.044
PM2.5	0.000
CO2	69.788
Fuel Use and Total Cost	
Fuel - Gallons	7,455
Idling Adjustment Gallons	2,036
Net Fuel Use Replacement Gallons	5,419

ii https://nepis.epa.gov/Exe/ZyNET.exe/P100FE3O.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2011+Thru+2015&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C11thru15%5CTxt%5C00000006%5CP100FE3O.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL

EV Charging Benefits

As Table 6 shows, the benefits estimate assumed that 5MW of the 12MW substation capacity would be used for electric yard and drayage tractor charging, and that yard tractor needs would have priority. The 5MW allocated to EV charging would thus support 16 yard tractors and 161 drayage tractors starting in 2025.

Table 6: Yard and Drayage Tractor Charging

Drayage Tractors and Yard Tractors					
Diesel to EV Replacements	**Start Year**	**Chargers**	**KW/H**	**Peak Load kW**	**Vehicles**
Drayage Tractors	2025	66	**70**	4640	161
Yard Tractors	2025	12	**30**	360	16
Total		**78**		**5000**	**177**

Table 7 shows the annual nominal and discounted values for the yard and drayage tractors. Following PIDP guidance for unit values and discounting, the estimated PVs are **$2,205,057** for yard tractors and **$12,677,840** for drayage tractors, a total EV charging PV of **$14,882,897**.

Table 7: Drayage and Yard Tractor Emissions Benefits

	Unit Emissions Mtons/yr	2025	2030	2035	2040	2045	2050	2052	Total
Drayage EVs									
Trucks converted from Diesel to EV		**161**	**161**	**161**	**161**	**161**	**161**	**161**	
Avg Annual Emissions MTons/Truck (Drayfleet)									
NOx	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	
PM2.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CO2	63.329	63.329	63.329	63.329	63.329	63.329	63.329	63.329	
Value/Mtons (PIDP Guidance)									
NOx		$ 16,600	$ 17,700	$ 18,000	$ 18,000	$ 18,000	$ 18,000	$ 18,000	
PM2.5		$ 782,700	$ 841,200	$ 852,700	$ 852,700	$ 852,700	$ 852,700	$ 852,700	
CO2		$ 55	$ 60	$ 65	$ 70	$ 75	$ 75	$ 75	
Annual Value									
NOx		$ 107,822	$ 114,966	$ 116,915	$ 116,915	$ 116,915	$ 116,915	$ 116,915	
PM2.5		$ 101	$ 109	$ 110	$ 110	$ 110	$ 110	$ 110	
Annual Value		$ 107,923	$ 115,075	$ 117,025	$ 117,025	$ 117,025	$ 117,025	$ 117,025	
Discounted @ 7%		**$ 82,334**	**$ 62,593**	**$ 45,384**	**$ 32,358**	**$ 23,071**	**$ 16,449**	**$ 14,368**	**$ 1,136,801**
CO2		$ 560,925	$ 611,919	$ 662,912	$ 713,905	$ 764,898	$ 764,898	$ 764,898	
Discounted @ 3%		**$ 498,375**	**$ 468,985**	**$ 438,263**	**$ 407,130**	**$ 376,279**	**$ 324,582**	**$ 305,949**	**$ 11,541,039**
Total		**$ 580,709**	**$ 531,578**	**$ 483,647**	**$ 439,488**	**$ 399,350**	**$ 341,031**	**$ 320,317**	**$ 12,677,840**
EV Yard Tractors									
Units converted from Diesel to EV		**16**	**16**	**16**	**16**	**16**	**16**	**16**	
Avg Annual Emissions MTons/Unit (2017 Inventory)									
NOx	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199	
PM2.5	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	
CO2	62.216	62.216	62.216	62.216	62.216	62.216	62.216	62.216	
Value/Mtons (PIDP Guidance)									
NOx		$ 16,600	$ 17,700	$ 18,000	$ 18,000	$ 18,000	$ 18,000	$ 18,000	
PM2.5		$ 782,700	$ 841,200	$ 852,700	$ 852,700	$ 852,700	$ 852,700	$ 852,700	
CO2		$ 55	$ 60	$ 65	$ 70	$ 75	$ 75	$ 75	
Annual Value									
NOx		$ 53,891	$ 57,462	$ 58,436	$ 58,436	$ 58,436	$ 58,436	$ 58,436	
PM2.5		$ 46,300	$ 49,760	$ 50,441	$ 50,441	$ 50,441	$ 50,441	$ 50,441	
Annual Value		$ 100,190	$ 107,222	$ 108,876	$ 108,876	$ 108,876	$ 108,876	$ 108,876	
Discounted @ 7%		**$ 76,435**	**$ 58,322**	**$ 42,224**	**$ 30,105**	**$ 21,465**	**$ 15,304**	**$ 13,367**	**$ 1,057,672**
CO2		$ 55,766	$ 60,836	$ 65,905	$ 70,975	$ 76,045	$ 76,045	$ 76,045	
Discounted @3%		**$ 49,547**	**$ 46,625**	**$ 43,571**	**$ 40,476**	**$ 37,409**	**$ 32,269**	**$ 30,417**	**$ 1,147,385**
Total		**$ 125,982**	**$ 104,947**	**$ 85,795**	**$ 70,581**	**$ 58,873**	**$ 47,573**	**$ 43,784**	**$ 2,205,057**

Assist Tugs

The Port of Oakland is a world leader in shorepower and cold ironing. One of the remaining vessel operations still using auxiliary diesel power is the Starlight Marine fleet of 3 assist tugs. These vessels will spend an estimated 60% of their total annual hours at berth and presently run 204 kWh auxiliary diesels at an estimated 25% load factor (

Table 8). Each tug thus consumes an estimated 268,056 kWh annually at berth. Based on the 2017 emissions inventory, each of the three tugs currently emits 1.69 mtons of NO_X, 0.061 mtons of $PM_{2.5}$, and 3,169.13 mtons of CO_2 from auxiliaries at berth annually.

Table 8: Assist Tug Auxiliary Emissions

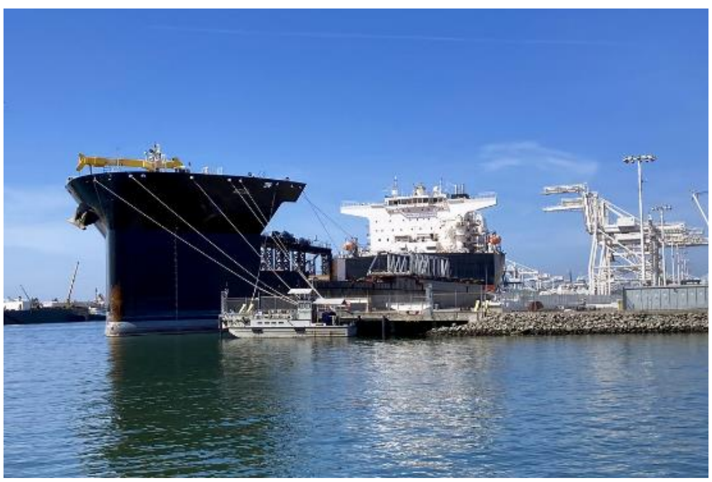
2017 Emission Inventory: Assist Tugs	
2017 Aux Emissions Mtons/yr*	
NOx	6.07
PM 2.5	0.22
CO2	11,439.46
% of tug time at berth	60%
Annual Idle/berth hours per tug	5,256
Aux kW - Starlight	204
% of berth time on Aux	100%
Aux Load Factor	0.25
Aux kWh	51
Annual Aux kWh/tug	**268,056**
2017 Aux Emissions tons/tug	
NOx	1.69
PM 2.5	0.06
CO2	3,186.13

Following PIDP guidance, Table 9 estimates the present value of emissions avoided by providing electrical shorepower in 2025-2052. The total discounted present value is estimated at **$14,533,067**.

Table 9: Assist Tug Emission Benefits

Unit Emissions Mtons/yr		2023	2030	2035	2040	2045	2050	2052	Total
Assist Tugs									
Annual Tugs Berthed		**3**	**3**	**3**	**3**	**3**	**3**	**3**	
Average Annual Emissions MTons/Tug									
NOx	1.690	1.690	1.690	1.690	1.690	1.690	1.690	1.690	
PM2.5	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	
CO2	3186.130	3186.130	3186.130	3186.130	3186.130	3186.130	3186.130	3186.130	
Value/Mtons (PIDP Guidance)									
NOx		$ 16,100	$ 17,700	$ 18,000	$ 18,000	$ 18,000	$ 18,000	$ 18,000	
PM2.5		$ 755,500	$ 841,200	$ 852,700	$ 852,700	$ 852,700	$ 852,700	$ 852,700	
CO2		$ 53	$ 60	$ 65	$ 70	$ 75	$ 75	$ 75	
Annual Value									
NOx		$ 81,631	$ 89,743	$ 91,264	$ 91,264	$ 91,264	$ 91,264	$ 91,264	
PM2.5		$ 137,419	$ 153,007	$ 155,099	$ 155,099	$ 155,099	$ 155,099	$ 155,099	
Annual Value		$ 219,049	$ 242,750	$ 246,363	$ 246,363	$ 246,363	$ 246,363	$ 246,363	
Discounted @ 7%		**$ 191,326**	**$ 132,040**	**$ 95,544**	**$ 68,121**	**$ 48,570**	**$ 34,629**	**$ 30,247**	**$ 2,766,684**
CO2		$ 506,595	$ 573,503	$ 621,295	$ 669,087	$ 716,879	$ 716,879	$ 716,879	
Discounted @ 3%		**$ 477,514**	**$ 439,543**	**$ 410,749**	**$ 381,571**	**$ 352,657**	**$ 304,205**	**$ 286,743**	**$ 11,766,383**
Total		**$ 668,840**	**$ 571,583**	**$ 506,293**	**$ 449,693**	**$ 401,227**	**$ 338,835**	**$ 316,989**	**$ 14,533,067**

Vessel Layberthing. Layberthing refers to extended berthing of vessels idle between assignments. The Port of Oakland has recently contracted with the U.S. Navy for layberthing of selected vessels. Those vessels most recently included:



- USNS *John Glenn* (T-ESD-2), an Expeditionary Transfer Dock ship under the Military Sealift Command, from September 2020 through the present (left).
- SS *Cape Mohican* (T-AKR-5065), a heavy-lift SEEBEE barge carrier in the Military Sealift Command Ready Reserve Force, from December 2017 to July 2021.

The Port estimates that future layberthing would typically include one vessel for a full year and one for about 3 months, the equivalent of 1.25 vessels on average.

Table 10 shows the estimated daily emissions from diesel auxiliary power on the USNS *John Glenn*, considered typical of layberthed vessels.

Table 10: Layberthing Auxiliary Power Emissions

Vessel	Hotelling Electric Demand (kW)	Percent of Aux Engine Capacity	Energy (kWh)	Daily Emissions in mtons		
				NOx	PM2.5	CO2
John Glenn	900	15%	21,600	0.2268	0.0036	14.6016

Table 11 applies these factors to the expected 1.25 vessels and 456.25 annual vessel day of layberthing, using the emissions values and discounting guidelines from PIDP and DOT. The estimated discounted present value of the benefits through 2030, when layberthing activity is expected to cease or diminish, is **$19,638,538**.

Table 11: Layberthing Emission Benefits

Unit Emissions Mtons/yr		2023	2030	2035	2040	2045	2050	2052	Total
Layberthing									
Annual Annual Layberthing Vessel-Days		**456.25**	**456.25**	**0**	**0**	**0**	**0**	**0**	
Average Emissions MTons/Vessel Day									
NOx	0.227	0.227	0.227	0.227	0.227	0.227	0.227	0.227	
PM2.5	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	
CO2	14.602	14.602	14.602	14.602	14.602	14.602	14.602	14.602	
Value/Mtons (PIDP Guidance)									
NOx		$ 16,100	$ 17,700	$ 18,000	$ 18,000	$ 18,000	$ 18,000	$ 18,000	
PM2.5		$ 755,500	$ 841,200	$ 852,700	$ 852,700	$ 852,700	$ 852,700	$ 852,700	
CO2		$ 53	$ 60	$ 65	$ 70	$ 75	$ 75	$ 75	
Annual Value									
NOx		$ 1,665,988	$ 1,831,552	$ -	$ -	$ -	$ -	$ -	
PM2.5		$ 1,250,836	$ 1,392,724	$ -	$ -	$ -	$ -	$ -	
Annual Value		$ 2,916,824	$ 3,224,276	$ -	$ -	$ -	$ -	$ -	
Discounted @ 7%		**$ 2,547,667**	**$ 1,753,793**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 17,080,310**
CO2		$ 353,085	$ 399,719	$ -	$ -	$ -	$ -	$ -	
Discounted @ 3%		**$ 332,816**	**$ 306,351**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 2,558,228**
Total		**$ 2,880,483**	**$ 2,060,144**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 19,638,538**

Solar Array Public Health Benefits

The monetized public health benefits of substituting solar power for the mix of sources currently used were estimated using values and methodology developed by EPA. The Benefits-per-kWh (BPK) values were developed to estimate the public health benefits of regional, state, or local-level investments in energy efficiency and renewable energy (EE/RE), and are appropriate for this application. The methods and values used in this analysis were devised from EPA's publication *"Estimating the Public Health Benefits of Energy Efficiency and Renewable Energy with EPA's Benefits-per-kWh Values*[iii]*"*. The analysis uses the EPA BPK values for Utility Solar Energy programs in California for a 7% discount rate to conform with the overall 7% discount rate specified in the DOT guidance.

As shown in Table 12, the planned solar array would have an overall capacity of 4 MW (4,000 kW). The annual expected power output of solar arrays depends on their geographic location and expected sun exposure. The expected annual power output of 6.2 MWh was estimated using the National Renewable Energy Laboratory PVWatts calculator[iv] calibrated for Oakland, and includes allowances for system losses and inverter efficiency. Utilization is set at 100%, as solar arrays do not have a range of adjustable outputs similar to fossil fuel sources.

[iii] https://www.epa.gov/statelocalenergy/estimating-health-benefits-kilowatt-hour-energy-efficiency-and-renewable-energy
[iv] https://pvwatts.nrel.gov/pvwatts.php

Table 12: Solar Array Benefits Factors

Category	Value
Capacity kW	4,000
Annual kWh (PVWatts Calc.)	6,216,827
Start Year	2025
Inflation value	3%
Discount Rate	7%
Utilization	100%
2017 Benefit cents per kWH (EPA)	
Low	0.58
High	1.31
Mean	**0.945**

The benefit calculation uses the mean of the EPA high and low BPK estimates for 2019, which is 0.945 cents per kwh (Table 13). The cumulative PV rises to $576,289 by 2052.

Table 13: Solar Array Public Health Benefits

		Annual Value							
		2025	2030	2035	2040	2045	2050	2052	Total
kWh consumed	**Current Dollars**	$ 43,055	$ 49,912	$ 57,862	$ 67,078	$ 77,761	$ 90,147	$ 95,637	
6,216,827	**Discounted Value**	$ 32,846	$ 27,149	$ 22,440	$ 18,548	$ 15,330	$ 12,671	$ 11,742	**$ 576,289**

Combined Present Value

As Table 14 shows, the combined present discounted value of emissions reduction from electric vehicles and shorepower and public health benefits from substitution of solar is **$49,630,790** through 2052.

Table 14: Project Benefit Summary

Project Benefits	Present Value
Electric Vehicle Charging and Emissions Reduction	
Yard Tractors	$ 2,205,057
Drayage Tractors	$ 12,677,840
Shorepower Emission Reduction	
Assist Tugs	$ 14,533,067
Layberthing	$ 19,638,538
Solar Array Public Health Benefits	$ 576,289
Total Present Value	**$ 49,630,790**

Benefit Cost Comparison

As shown in Table 15, the project would yield an estimated Net Present Value (NPV) of **$30,683,441**, and a Benefit-Cost Ratio (BCR) of **2.62**.

Table 15: Benefit-Cost Comparisons

Net Present Value and Benefit-Cost Ratio	Present Value
Project Benefits	$ 49,630,790
Project Cost	$ 18,947,350
Net Present Value	$ 30,683,441
Benefit-Cost Ratio	**2.62**

Figure 1 shows that the project yields cumulative Net Present Value beginning in 2027 as electric drayage tractors and yard tractors are deployed and use the increased grid capacity.

Figure 1: Cumulative PV Benefits and Costs