US Army Corps
of Engineers®
Portland District

WILLAMETTE VALLEY SYSTEM OPERATIONS AND MAINTENANCE

FINAL ENVIRONMENTAL IMPACT STATEMENT

APPENDIX U: AIR QUALITY AND GREENHOUSE GAS EMISSIONS ANALYSIS

NEW APPENDIX ADDED TO THE FINAL EIS

TABLE OF CONTENTS

LIST OF TABLES

THIS APPENDIX HAS BEEN ADDED TO THE FEIS TO SUPPORT THE ALTERNATIVES ANALYSES IN SECTION 3.10, AIR QUALITY AND GREENHOUSE GAS EMISSIONS

Photo by Mike Pomeroy (USACE Media Images Database)

Smoke from the Beachie Creek fire engulfs Detroit Dam, August 2020.

1 - INTRODUCTION

Three analyses were conducted to evaluate the effects of alternatives on air quality and greenhouse gas emissions, including (1) fish trucking and emergency generator air quality and greenhouse gas emissions, (2) power generation-related carbon dioxide emissions, and (3) social cost of carbon (SC-CO2) for a 30-year implementation timeframe (years 2020 to 2050). Fish trucking and emergency generator air quality and greenhouse gas emissions were estimated using the USACE (2023) Net Emissions Analysis Tool (NEAT) model, and power generation-related carbon dioxide emissions were estimated using a marginal emissions analysis. The SC-CO2 related to estimated emissions was subsequently calculated based on published annual social cost of greenhouse gas emission estimates for years 2020 to 2050.

As context, an emission "source" produces greenhouse gasses; a "sink" reduces or offsets emissions. A sink example is the removal of carbon dioxide from the atmosphere through forest, soil, and vegetation carbon uptake and storage. The NEAT model records wetland and aquatic habitat to address emission sinks.

2 - METHODOLOGY AND RESULTS

2.1 FISH TRUCKING AND EMERGENCY GENERATOR AIR QUALITY POLLUTANT AND GREENHOUSE GAS EMISSIONS

The USACE (2023) NEAT model was used to assess fish trucking and emergency generator air quality pollutant and greenhouse gas emissions. The NEAT model was developed by the USACE Air Quality and Greenhouse Gas Emissions Analysis Sub-Community of Practice to utilize output data from pre-existing industry-standard emissions models for air pollutant and greenhouse gas emissions inputs.

NEAT leverages the benefits of pre-existing models while innovating new capabilities for quantifying emissions using an expandable tabular methodology (Excel) that can accommodate additional greenhouse gas sources and sinks as needed. NEAT combines results from these sources and sinks to calculate the emissions for air pollutants and greenhouse gases.

Assumptions for this analysis include:

<u>Fish Trucking</u>:

- Approximately 92,000 miles would continue to be driven annually for 11 fish release sites under the No-action Alternative (NAA).
- 92,576 miles driven annually for 17 fish release sites (i.e., existing release sites plus six new release sites) under Alternatives 1, 2A, 2B, 4, and 5.
- 93,216 miles driven annually for 18 fish release sites (i.e., existing release sites plus seven new release sites) under Alternative 3A and Alternative 3B (Section 3.10.2.1, Air Emissions from U.S. Army Corps of Engineers’ Operations and Maintenance Activities).
- Emission factors of light-medium duty trucks used in the WVS are considered equivalent to those identified by the South Coast Air Quality Management District (SCAQMD No Date-a) for delivery trucks (greater than 8,500 pounds)[1]. SCAQMD mobile source factors are based on the “Highest (Most Conservative) EMFAC2007 (version 2.3) Emission Factors for On-Road Passenger Vehicles & Delivery Trucks.”

[1] SCAQMD on-road passenger vehicle and delivery truck emission factors include reactive organic gases (ROG), carbon monoxide (CO), sulfur oxides (SOx), nitrogen oxides (NOx), particulate matter (PM)10, PM2.5, carbon dioxide (CO2), and methane (CH4).

Emergency Generators:

- Emergency generators (average 250 maximum horsepower [max HP] at 183.4 kilowatt [kW]) would be operated up to 100 hours annually with up to 22 emergency generators operated under the NAA.

- Up to 29 emergency generators would be operated under Alternatives 1, 2A, 2B, 4, and 5.

- Up to 32 emergency generators would be operated under Alternative 3A and Alternative 3B.

- Emission factors of emergency generators used in the WVS are considered equivalent to those identified by SCAQMD (No Date-b) for 250 max HP (183.4 kW) generator sets under Scenario Year 2023[2]; these factors are composites with incorporated load factor ratings.

Underestimation of one or more air quality pollutants and greenhouse gases is possible if the associated SCAQMD emission factor is lower than the actual factor.

2.1.1 Estimated Fish Trucking and Emergency Generator Air Quality Pollutant and Greenhouse Gas Emissions

Table 1 presents the estimated annual and 30-year implementation timeframe amounts of air quality pollutant and greenhouse emissions associated with fish trucking and emergency generators combined for the NAA and action alternatives.

[2] SCAQMD diesel off-road-mobile source emission factors include ROG, CO, SOx, NOx, PM, CO2, and CH4. Based on PM conversion factors identified in Krause and Smith (2006), the PM2.5 and PM10 components were calculated by multiplying the PM values by 0.937 and 0.90, respectively.

Table 1. Estimated Air Quality Pollutants and Greenhouse Gas Emissions of Fish Trucking and Emergency Generators Combined.

No-action Alternative	Yearly Emissions			30-Year Implementation Timeframe Emissions		
Air Quality Pollutant Emissions	**Grams**	**Pounds**	**Metric Tons**	**Grams**	**Pounds**	**Metric Tons**
Reactive Organic Gases aka Volatile Organic Compounds (ROG/VOC)	104,790.55	231.02	0.10	3,143,716.36	6,930.71	3.14
Carbon Monoxide (CO)	650,747.07	1,434.65	0.65	19,522,412.24	43,039.59	19.52
Sulfur Oxides (SOx)	505,105.12	1,113.57	0.51	15,153,153.58	33,407.01	15.15
Nitrous Oxides (NOx)	285,806.30	630.10	0.29	8,574,188.99	18,902.87	8.57
Particulate Matter - 2.5 micron ($PM_{2.5}$)	23,075.08	50.87	0.02	692,252.41	1,526.16	0.69
Particulate Matter - 10 micron (PM_{10})	27,134.14	59.82	0.03	814,024.28	1,794.62	0.81
Greenhouse Gas Emissions						
Carbon Dioxide (CO_2)	332,514,247.84	733,069.03	332.51	9,975,427,435.32	21,992,070.93	9,975.45
Methane (CH_4)	7,348.40	16.20	0.01	220,452.12	486.01	0.22
Nitrous Oxide (N_2O)	285,806.30	630.10	0.29	8,574,188.99	18,902.87	8.57
Alternatives 1, 2A, 2B, 4, 5	**Yearly Emissions**			**30-Year Implementation Timeframe Emissions**		
Air Quality Pollutant Emissions	**Grams**	**Pounds**	**Metric Tons**	**Grams**	**Pounds**	**Metric Tons**
Reactive Organic Gases aka Volatile Organic Compounds (ROG/VOC)	137,473.72	303.08	0.14	4,124,211.70	9,092.34	4.12
Carbon Monoxide (CO)	858,079.97	1,891.74	0.86	25,742,399.19	56,752.32	25.74
Sulfur Oxides (SOx)	551,651.99	1,216.19	0.55	16,549,559.83	36,485.56	16.55
Nitrous Oxides (NOx)	464,696.39	1,024.48	0.46	13,940,891.60	30,734.43	13.94
Particulate Matter - 2.5 micron ($PM_{2.5}$)	30,257.08	66.71	0.03	907,712.28	2,001.16	0.91
Particulate Matter - 10 micron (PM_{10})	35,744.14	78.80	0.04	1,072,324.30	2,364.07	1.07
Greenhouse Gas Emissions						
Carbon Dioxide (CO_2)	427,464,877.10	942,399.51	427.47	12,823,946,313.06	28,271,985.20	12,823.97
Methane (CH_4)	8,966.09	19.77	0.01	268,982.62	593.01	0.27
Nitrous Oxide (N_2O)	464,696.39	1,024.48	0.46	13,940,891.60	30,734.43	13.94

Alternatives 3A and Alternative 3B	Yearly Emissions				30-Year Implementation Timeframe Emissions		
Air Quality Pollutant Emissions	**Grams**	**Pounds**	**Metric Tons**		**Grams**	**Pounds**	**Metric Tons**
Reactive Organic Gases aka Volatile Organic Compounds (ROG/VOC)	153,388.09	338.16	0.15		4,601,642.61	10,144.89	4.60
Carbon Monoxide (CO)	956,315.42	2,108.32	0.96		28,689,462.67	63,249.49	28.69
Sulfur Oxides (SOx)	643,404.14	1,418.46	0.64		19,302,124.33	42,553.93	19.30
Nitrous Oxides (NOx)	495,937.41	1,093.36	0.50		14,878,122.44	32,800.67	14.88
Particulate Matter - 2.5 micron ($PM_{2.5}$)	33,763.47	74.44	0.03		1,012,904.08	2,233.07	1.01
Particulate Matter - 10 micron (PM_{10})	39,652.90	87.42	0.04		1,189,586.92	2,622.59	1.19
Greenhouse Gas Emissions							
Carbon Dioxide (CO_2)	479,150,158.62	1,056,346.14	479.15		14,374,504,758.46	31,690,384.22	14,374.53
Methane (CH_4)	10,173.45	22.43	0.01		305,203.62	672.86	0.31
Nitrous Oxide (N_2O)	495,937.41	1,093.36	0.50		14,878,122.44	32,800.67	14.88

2.2 POWER GENERATION-RELATED GREENHOUSE GAS EMISSIONS

Hydropower generation itself produces very little greenhouse gas emissions; therefore, a marginal emissions analysis was performed to assess power generation-related greenhouse gas emissions. This approach is commonly used to assess greenhouse gas emissions related to a power generation system consisting of individual hydropower facilities (WPTO No Date). It involves calculating the marginal increase in greenhouse gas emissions across the system for given changes in electricity demand.

For purposes of this analysis, it was assumed that an increase in average annual hydropower generation (aMW) would result in a commensurate decrease in fossil fuel-based (e.g., natural gas) generation, whereas a decrease in hydropower would result in a commensurate increase in fossil fuel-based generation. Decreases or increases in fossil fuel-based generation would result in corresponding decreases or increases in greenhouse gas emissions and associated SC-CO2.

The analysis focused on quantifying carbon dioxide emissions because these emissions are the primary source of greenhouse gas emissions from power generation in Oregon, accounting for over 99 percent of energy-related emissions in 2022 (EIA 2023), and there were readily available marginal carbon dioxide emission rates reported for the Pacific Northwest region by the Northwest Power and Conservation Council (NWPCC 2018).

Marginal carbon dioxide emissions are calculated for each action alternative based on the difference in the estimated average annual hydropower generation produced compared to the NAA. According to Holland et al. (2022), "Marginal emission rates, in contrast to average emissions (i.e., carbon intensity)[3], are critical for the evaluation of electricity-shifting climate policies in the United States." Therefore, because electricity-sector greenhouse gas emissions are a focus of evolving regulatory and policy initiatives in Oregon and the Pacific Northwest, this analysis quantifies the effects of the alternatives on carbon dioxide emissions from power generation based on an annual range for marginal carbon dioxide emissions rates instead of average emissions. Marginal carbon dioxide emissions were calculated for each action alternative by:

(1) using the differences in the estimated 73-year average hydropower generation that would be produced under each alternative relative to the NAA from Appendix G, Power and Transmission, and

[3] Average emissions describe the carbon intensity of the grid in a defined area based on the predominant generation sources (i.e., the aggregated emissions from all the hydroelectric, gas, solar, and wind power plants that supply power to the area) (Holland et al. 2020; Sustainable Campus 2022). The marginal emissions rate is the rate at which emissions change due to adjustments in electrical load in a specific timeframe (i.e., when customers increase or decrease electricity use, certain power plants adjust to match that increase or decrease) (Sustainable Campus 2022).

(2) multiplying these differences by the low and high marginal carbon dioxide emission rates (0.91 pounds per kW-hour to 1.83 pounds per kW-hour) reported for the Pacific Northwest region by the Northwest Power and Conservation Council (NWPCC 2018).

2.2.1 Estimated Power Generation-related Greenhouse Gas Emissions

Table 2 presents the estimated range of annual average carbon dioxide emissions under each alternative calculated based on marginal carbon dioxide emissions rates ranging from a low scenario (0.91 pounds per kilowatt-hour) to a high scenario (1.83 pounds per kilowatt-hour)—as reported for the Pacific Northwest region by the Northwest Power and Conservation Council (2018)—applied to the predicted differences in WVS projects' 73-year average hydropower generation amounts (from Appendix G, Power and Transmission) between each alternative and the NAA.

Table 2. Estimated Annual Average Carbon Dioxide Emissions in Thousand Metric Tons from Power Generation by Alternative.

MCDPR Scenario	NAA*	ALT 1 Difference from NAA	ALT 2A Difference from NAA	ALT 2B Difference from NAA	ALT 3A Difference from NAA	ALT 3B Difference from NAA	ALT 4 Difference from NAA	ALT 5 Difference from NAA
Low**	-	-28.93	+14.46	+65.09	+314.58	+285.66	-3.62	+68.7
High**	-	-58.17	+29.09	+130.89	+632.62	+574.45	-7.27	+138.16

MCDPR = Marginal carbon dioxide production rate

* Hydropower generation itself produces very little greenhouse gas emissions; therefore, no carbon dioxide emissions are calculated for the NAA. Carbon dioxide emissions occur because of a change in hydropower generation from implementing an alternative (i.e., an increase or decrease in hydropower generation results in a commensurate decrease or increase, respectively, in carbon dioxide emitting fossil fuel-based generation).

**MCDPR low and high scenarios represent values estimated using the low and high end of the annual range, respectively, for the marginal CO2 emissions rates (0.91 pounds/kilowatt-hour to 1.83 pounds/kilowatt-hour) reported for the Pacific Northwest region by the Northwest Power and Conservation Council (NWPCC 2018).

2.3 SOCIAL COST OF CARBON

Greenhouse gas emissions influence a variety of socioeconomic outcomes related to climate change, including agricultural productivity, human health, flood risk, infrastructure, and fishery damages. The value of reducing levels of greenhouse gases in the atmosphere is the avoided damages that would be generated by a unit of greenhouse gas if it were present. Economists express this value in monetary terms representing society's willingness to pay to avoid climate-related impacts associated with an additional unit of a greenhouse gas in the atmosphere. This value is defined as the "social cost" of greenhouse gases. The more common term, "social cost of carbon or SC-CO2," generally pertains to carbon dioxide emissions. The SC-CO2 is used in this analysis consistent with the greenhouse gas emissions analyses.

On January 6, 2023, the White House Council of Environmental Quality released new *Guidance on Consideration of Greenhouse Gas Emissions and Climate Change*. This guidance indicates that agencies should contextualize greenhouse gases associated with a project after quantifying them, which can include monetizing climate damages using the "best available estimates" of the social cost of greenhouse gases and placing emissions in the context of relevant climate goals and commitments.

There is currently a lack of consensus on the best available social cost of greenhouse gas estimates to use for calculating the SC-CO2. In 2021, a United States Interagency Working Group (IWG) on the Social Cost of Greenhouse Gases issued interim SC-CO2 estimates per metric ton of carbon dioxide (Table 3) (IWG 2021).

The IWG (2021) recommends using four discount rates to capture uncertainties involved in analyses. However, these estimates have been the subject of litigation and the IWG had not issued final estimates at the time the alternatives were analyzed.

For comparison, EPA issued a regulatory document in 2022 that estimated the SC-CO2 at $190/ton using 2020 dollars at a 2 percent discount rate (EPA 2022). Despite the ongoing lack of consensus, the Council on Environmental Quality (88 FR 1196) indicates that agencies should apply the "best available estimates," which are the IWG (2021) interim estimates. Table 3 lists these four estimates, which are used in the analysis. As per best practices, the 3 percent discount rate is considered the central estimate.

Table 3. Annual SC-CO2, 2020 to 2050 in 2020 U.S. Dollars Per Metric Ton of CO_2.

Emissions Year	Discount Rate			
	5.0% Average ($)	3.0% Average ($)	2.5% Average ($)	3% High Impact (95th percentile) ($)
2020	14	51	76	152
2021	15	52	78	155
2022	15	53	79	159
2023	16	54	80	162
2024	16	55	82	166
2025	17	56	83	169
2026	17	57	84	173
2027	18	59	86	176
2028	18	60	87	180
2029	19	61	88	183
2030	19	62	89	187
2031	20	63	91	191
2032	21	64	92	194
2033	21	65	94	198
2034	22	66	95	202
2035	22	67	96	206

Emissions Year	Discount Rate			
	5.0% Average ($)	3.0% Average ($)	2.5% Average ($)	3% High Impact (95th percentile) ($)
2036	23	69	98	210
2037	23	70	99	213
2038	24	71	100	217
2039	25	72	102	221
2040	25	73	103	225
2041	26	74	104	228
2042	26	75	106	232
2043	27	77	107	235
2044	28	78	108	239
2045	28	79	110	242
2046	29	80	111	246
2047	30	81	112	249
2048	30	82	114	253
2049	31	84	115	256
2050	32	85	116	260

Source: IWG 2021

% = percent, $ = U.S. dollars

Values are the average across models and socioeconomic emissions scenarios for each of three discount rates (2.5%, 3%, and 5%), plus a fourth value, selected as the 95th percentile of estimates based on a 3 percent discount rate.

2.3.1 Estimated Social Cost of Carbon associated with Estimated Fish Trucking and Emergency Generators

Table 4 presents the total present-value estimates of the SC-CO2 (in 2020 U.S. dollars) from carbon dioxide emissions for fish trucking and emergency generators combined under each alternative. These total present-value estimates for each alternative were calculated under the four discount rate assumptions by (1) multiplying each of the annual SC-CO2 published estimates for 2020 to 2050 from Table 3 by (2) the relevant average annual carbon emission estimates from Table 1, and (3) totaling the calculated results of all 30 years under each discount rate. The total present-value estimates reflect the value of the changes in carbon dioxide emissions under each alternative over the 30-year implementation timeframe relative to the NAA.

Table 4. Total Discounted Social Cost of Carbon (SCC) Estimates (Present Value) for Fish Trucking and Emergency Generators under Each Alternative and Discount Rate in Thousands of 2020 U.S. Dollars (2020 to 2050).

Alternative	Total Discounted SCC Estimates in Thousands 2020 U.S. Dollars ($)			
	Present Value 5% Average	Present Value 3% Average	Present Value 2.5% Average	Present Value 3% (95th)
No-action	227	679	968	2,068
Alternatives 1, 2A, 2B, 4, 5	273	817	1,164	2,487
Alternative 3A and Alternative 3B	293	877	1,250	2,670

%=percent

2.3.2 Estimated Social Cost of Carbon associated with power generation

Table 5 and Table 6 present the total present-value estimates of the SC-CO2 (in 2020 U.S. dollars) from carbon dioxide emissions associated with power generation under each alternative. Total present-value estimates for each alternative were calculated under the four discount rate assumptions by (1) multiplying each of the annual SC-CO2 published estimates for 2020 to 2050 from Table 3 by (2) the relevant average annual power generation-related emission estimates under low and high marginal CO_2 emissions rate scenarios from Table 2, and (3) totaling the calculated results of all 30 years under each discount rate.

The total present-value estimates of the action alternatives reflect the value of the changes in carbon dioxide emissions under each alternative over the 30-year implementation timeframe relative to the NAA. All estimated SC-CO2 values are presented in millions of 2020 U.S. dollars, rounded to whole dollars.

Table 5. Total Discounted Social Cost of Carbon (SC-CO2) Estimates (Present Value) for Power Generation under Each Alternative and Discount Rate in Millions of 2020 U.S. Dollars (2020 to 2050) Assuming a Marginal Carbon Dioxide Emissions Rate of 0.91 pounds/kilowatt-hour.

Alternative	Total Discounted SCC Estimates in Millions of 2020 U.S. Dollars ($)			
	Present Value 5% Average	Present Value 3% Average	Present Value 2.5% Average	Present Value 3% (95th)
No-action*	-	-	-	-
Difference from No-action				
Alternative 1	-23	-68	-97	-207
Alternative 2A	+11	+34	+48	+104
Alternative 2B	+52	+153	+217	+466

Alternative	Total Discounted SCC Estimates in Millions of 2020 U.S. Dollars ($)			
	Present Value 5% Average	Present Value 3% Average	Present Value 2.5% Average	Present Value 3% (95th)
Alternative 3A	+250	+739	+1,050	+2,252
Alternative 3B	+227	+671	+953	+2,045
Alternative 4	-3	-9	+12	-26
Alternative 5	+55	+161	+229	+492

% = percent

* Hydropower generation itself produces very little greenhouse gas emissions; therefore, no carbon emissions are calculated for the NAA, resulting in no SC-CO2 estimates calculated for the NAA. Carbon dioxide emissions occur from a change in hydropower generation because of implementing an alternative (i.e., an increase or decrease in hydropower generation results in a commensurate decrease or increase, respectively, in carbon dioxide emitting fossil fuel-based generation). Therefore, SC-CO2 values for all action alternatives are depicted as an increase or decrease relative to the NAA. Values represent total discounted SC-CO2 estimates in millions of 2020 U.S. dollars rounded to two significant digits.

Table 6. Total Discounted Social Cost of Carbon (SCC) Estimates (Present Value) for Power Generation under Each Alternative and Discount Rate in Millions of 2020 U.S. Dollars (2024 to 2050) Assuming a Marginal Carbon Dioxide Emissions Rate of 1.83 pounds/kilowatt-hour.

Alternative	Total Discounted SCC Estimates in Millions of 2020 U.S. Dollars ($)			
	Present Value 5% Average	Present Value 3% Average	Present Value 2.5% Average	Present Value 3% (95th)
No-action*	-	-	-	-
Difference from No-action				
Alternative 1	-46	-137	-194	-416
Alternative 2A	+23	+68	+97	+208
Alternative 2B	+104	+308	+437	+937
Alternative 3A	+503	+1,487	+2,111	+4,530
Alternative 3B	+456	+1,350	+1,917	+4,113
Alternative 4	-6	-17	-24	-52
Alternative 5	+110	+325	+461	+989

* Hydropower generation itself produces very little greenhouse gas emissions; therefore, no carbon emissions are calculated for the NAA, resulting in no SC-CO2 estimates calculated for the NAA. Carbon dioxide emissions occur from a change in hydropower generation because of implementing an alternative (i.e., an increase or decrease in hydropower generation results in a commensurate decrease or increase, respectively, in carbon dioxide emitting fossil fuel-based generation). Therefore, SC-CO2 values for all action alternatives are depicted as an increase or decrease relative to the NAA. Values represent the discounted SC-CO2 estimates in millions of 2020 U.S. dollars rounded to two significant digits.

3 - REFERENCES

Congressional Budget Office (CBO). 2022. Emissions of Carbon Dioxide in the Electric Power Sector. December 2022. 19 pages. Available at: http://www.cbo.gov/publication/58419

U.S. Energy Information Administration (EIA).2023. Oregon State Energy Profile. Available at: https://www.eia.gov/state/print.php?sid=OR

U. S. Environmental Protection Agency (EPA). 2022. Supplementary Material for the Regulatory Impact Analysis for the Supplemental Proposed Rulemaking, "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review." EPA external review draft of Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances. National Center for Environmental Economics, Office of Policy, Climate Change Division, Office of Air and Radiation, U.S. Environmental Protection Agency. Washington, DC. Docket ID No. EPA-HQ-OAR-2021-03. September 2022. 137 pages. Available at: https://www.epa.gov/system/files/documents/2022-11/epa_scghg_report_draft_0.pdf

Holland, S., M. Kotchen, E. Mansur, and A. Yates. 2020. Why are Marginal CO2 Emissions Increasing for U.S. Electricity? Estimates and Implications for Climate Policy. November 4, 2020. Available at: https://www.aeaweb.org/conference/2021/preliminary/paper/nsArAYeQ

Krause, M. and S. Smith. 2006. Final Methodology to Calculate Particulate Matter (PM) 2.5 and PM 2.5 Significance Thresholds. October 2006. 8 pages plus appendices. Available at: https://www.aqmd.gov/docs/default-source/ceqa/handbook/localized-significance-thresholds/particulate-matter-(pm)-2.5-significance-thresholds-and-calculation-methodology/final_pm2_5methodology.pdf

Interagency Working Group (IWG) on Social Cost of Greenhouse Gases, United States Government. 2021. Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990. February 2021. 48 pages. Available at: https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf

Northwest Power and Conservation Council (NWPCC). 2018. Avoided Carbon Dioxide Production rates in the Northwest Power System. March 13, 2018. Document 2018-1. Available at: https://www.nwcouncil.org/sites/default/files/2018-1.pdf

South Coast Air Quality Management District (SCAQMD). No Date-a. EMFAC 2007 (v2.3) Emission Factors (On-Road). Available at: https://www.aqmd.gov/home/rules-compliance/ceqa/air-quality-analysis-handbook/emfac-2007-(v2-3)-emission-factors-(on-road)

SCAQMD. No Date-b. Off-road Mobile Source Emission Factors. Available at: https://www.aqmd.gov/home/rules-compliance/ceqa/air-quality-analysis-handbook/off-road-mobile-source-emission-factors

Sustainable Campus. 2022. mer-vs-aer: Marginal Emissions Rate vs. Average Emissions Rate. Available at: https://sustainablecampus.cornell.edu/news/mer-vs-aer

U.S. Army Corps of Engineers (USACE). 2023. National Certification of the Net Emissions Analysis Tool. Memorandum for Chief, Civil Works Engineering, USACE Headquarters, Vanessa Bateman, CECW-EC. Signed by Kelly J. Keefe, PhD Chief, MVD Planning and Policy and Director, Ecosystem Restoration Planning Center of Expertise. December 15, 2023.