Technical Appendix

This technical appendix explains the methodology and assumptions used for developing the estimated greenhouse gas (GHG) emissions and co-pollutant emissions reduced for each measure included in the proposal. The "GHG Emission Reduction Calculation Spreadsheet" included with this application provides the specific GHG emission reduction calculations for each measure.

A.1 Emissions Reduction Estimate Method

The estimation method for this measure used spreadsheet calculations to estimate displaced fossil fuel energy – as a result of freight trucks charging with electricity instead of diesel fuel – and associated emission reductions using data gathered from various sources. For comparison, the additional emissions resulting from electricity generated to power the charging stations were also estimated but not included in the workplan outline, for reasons explained below

A.2 Models/Tools Used

Tailpipe emission rates for CO_2e (including CO_2, CH_4, and N_2O), NO_X, VOC, and PM2.5 were developed by Sonoma Technology under contract to the Northeast States for Coordinated Air Use Management (NESCAUM) using the U.S. EPA MOVES4 model. For comparison, electricity generation emissions were also generated by Sonoma Technology using projections developed by NESCAUM. All emissions rates are based on state-specific analysis, with a weighted average of state values based on the proportion of investment going to each of the participating states.

A.3 Measure Implementation Assumptions

The following key assumptions about measure implementation were used to quantify emissions reductions for this measure.

Scenarios:

Scenario 1: The total number of charging ports would be constructed at an estimated 24 discreet sites along the corridor in a manner consistent with the following illustrative scenario assuming that 50 percent of estimated grid upgrade costs are covered by C3 grant funding (Scenario 1):

Table II.1 – Total Number of Charging Ports Constructed under Scenario 1

Charger Nominal Max Power Level	Total Regional	Connecticut	Delaware	Maryland	New Jersey
150 kW	148	36	10	47	55
350 kW	164	39	9	55	61
1,000 kW	138	33	6	48	51

Scenario 2: In this alternative scenario, it is assumed that 100 percent of grid upgrades are covered by C3 grant funding and fewer charging ports are built as a result of this measure. While C3 states are intending to encourage site hosts to pay for any grid upgrades that are needed to make the project operational -- to make

their grant proposals for funding more competitive -- this emissions scenario is explored recognizing that grid upgrades are often required to accommodate the installation of electric vehicle charging sites and site hosts may not be in a position to cover these costs (e.g., if a state issues a request for proposals to develop a charging site on public land, owned by one of the coalition states, any costs associated with necessary grid upgrades would necessarily be covered by grant funding). For this alternative scenario 2, the total number of estimated new charging ports is shown in Table II.2.

Table II.2 – Total Number of Charging Ports Constructed under Scenario 2

Charger Nominal Max Power Level	Total Regional	Connecticut	Delaware	Maryland	New Jersey
150 kW	124	26	0	43	55
350 kW	132	31	7	45	49
1,000 kW	106	27	8	36	35

Implementation Timeline:

- In 2026 and 2027, RFP's would be issued.
- In 2027 and 2028, contracts would be put in place for design and construction.
- Roughly half of the charging ports would be constructed by 2029 and the remainder by 2030.
- All sites would be fully constructed and active as of 2030.

Sites would continue to be active and providing benefits through 2050. While some of the equipment at the sites (such as charging stations) would likely reach the end of their lifetime and need to be replaced before 2050, it is assumed that by the time replacement is needed, replacement costs would be covered through the private sector as recouped from charging fees. Other components, such as upgraded grid infrastructure, would have a lifespan extending beyond 2050. Furthermore, the project is anticipated to be a necessary element in spurring a transition to zero-emission trucks that will provide lasting benefits. Without this initial public investment, these lasting benefits will not be realized.

A.4 Charging Site Design and Cost Estimate Assumptions

To estimate the cost of purchasing and installing charging units, as well as required utility upgrades, the Coalition developed a simplified methodology based on data from a 2022 report from the National Renewable Energy Laboratory (NREL). This report estimates the breakeven cost of charging for electric Class 8 tractor trucks under various scenarios which consider different factors such as charging location, installation costs, utility rates, and vehicle adoption rates.

NREL estimated costs were incorporated using the following three-step methodology.

Step 1: Develop illustrative site designs for three different types of charging stations:

The Coalition developed three different site designs intended to illustrate the types of public charging use cases that could theoretically serve the emerging zero emission long-haul freight market.

Each site type is assumed to be a mix of charging ports at three different maximum power levels: 150 kW, 350 kW, and 1 MW (1,000 kW), with each power level corresponding to different expected use cases (Table II.3).

Table II.3 – Illustrative site designs for three different types of charging stations

		Number of Ports at each Site Type		
Use Cases for Charger Power Levels	**Charger Nominal Max Power Level**	**Smaller Truck Stop**	**Larger Truck Stop**	**Industrial Stop**
Overnight	150 kW	8	10	--
Opportunity fast	350 kW	6	8	6
Opportunity ultra-fast	1,000 kW	3	6	8
Maximum site charging capacity:		6,300 kW	10,300 kW	10,100 kW

Step 2: Define the scope of costs to include in this analysis:

The Coalition agreed on three types of investments that would be eligible for funding under this program 1) Electric Vehicle Supply Equipment (EVSE) purchase, 2) EVSE installation, and 3) necessary utility upgrades.

Step 3: Estimate the costs for each charging site, or station:

For each power level of charger, the costs of purchase, installation, and utility upgrades are estimated on a per kW basis using data from the NREL report.

Purchase costs of the charger units ("Unit" costs in the table below) represent the costs for buying and delivering the chargers to the site. These $/kW values for the charging units are derived from the 'high' values in Table 7 in the NREL report. Given the large degree of uncertainty in estimating costs of truck-specific charging stations, the Coalition used the 'high' values from the NREL report for each of the three per kW cost elements (i.e., the charging units, installation, and utility upgrades) to err on the conservative side in this analysis.

Installation costs include all wiring, conduit, protection, and other facility equipment upgrades, as well as construction costs such as trenching that may be required. This metric is meant to capture all of the installation and construction costs—with the exception of the purchase of the charging unit—for everything on the charging station side of the utility meter. As a simplification, we assume that the $/kW costs for the 350 kW and 1 MW chargers are identical to the costs for the 150 kW and 3 MW chargers, respectively, from the NREL study. The $/kW installation costs are derived from Table 9 in the NREL report.

In addition to all the installation costs on the facility side of the electric meter, many charging stations will require upgrades to equipment on the utility side of the meter. The level of utility upgrades required to support interconnection to the grid can vary greatly based on the site's peak demand and the current capacity of the grid at a particular location. Although these costs are sometimes covered completely or in part by the utility, this analysis assumes that 50 percent of upgrade costs will be covered by grant funding from the C3 measure. The $/kW utility upgrade costs in the table below are calculated from Table 10 in the NREL report by dividing the "Utility Upgrade Costs ($K)" values by the "Site Peak Demand (MW)" values.

Table II.4 - Per kW Costs for Charger Purchase, Installation, and Utility Upgrades

Charger Nominal Max Power Level	Unit	Installation	Utility Upgrades
150 kW	$416	$1,080	$578
350 kW	$416	$1,080	$578
1,000 kW	$300	$65	$500

A.5 Emission Reduction Estimate Assumptions

The following key assumptions about emission reductions were used to quantify emission reductions for this measure:

Average charge power for vehicles using the charging ports will be approximately 85 percent of the theoretical maximum power. This is consistent with assumptions in ICCT (2021).

Average utilization level (percent of time a port is in use) will reach a maximum of 30 percent in 2035 and beyond. This is consistent with assumed values or ranges of values found in the following sources:

- RMI (2020), in a national assessment of charging infrastructure needs for light-duty vehicles. assumes a 30 percent utilization of chargers at market maturation.
- The National Grid *Electric Highways* study (2022), which includes medium and heavy vehicles, also assumes 30 percent long-term utilization.
- ICCT (2021), in a national assessment of infrastructure needs to support a zero-emission tractor-trailer fleet, assumes that fast and megawatt chargers will see 12 vehicles per day charging for 30 minutes each (25 percent utilization).
- Atlas Public Policy (2021), in an estimate of the need for public on-road megawatt charging, provides both a low-cost scenario, in which 10 percent of truck charging is onroad at 40 percent utilization; and a high-cost scenario, in which 25 percent of truck charging is onroad at 20 percent utilization.
- Burke and Miller (2020), in an assessment for California, assume 24 percent utilization.

Note: It is considered that utilization rates in the I-95 corridor are likely to be at least as high, if not higher than, national averages given that this is a high-truck traffic corridor, so an assumption of 30 percent utilization was selected over more conservative ranges of 20 to 24 percent.

Before 2035, the average utilization level will ramp up in proportion to the estimated stock share of medium and heavy trucks vs. the 2035 share, as based on projections for California's Advanced Clean Trucks (ACT) regulations, which have been adopted by three of the four participating states. Use of 150 kW and 350 kW chargers was ramped up in proportion to the share of medium-duty trucks, and use of 1 MW chargers was ramped up in proportion to the share of heavy-duty trucks.

The relevant assumptions for each charger power level are shown in Table II.5.

Table II.5 - Charger Power Level and Utilization Assumptions

Max Power (kW)	Avg Charge Power (kW)	2029	2030	2031	2032	2033	2034	2035+
150 kW	120	7%	10%	14%	17%	21%	26%	30%
350 kW	300	7%	10%	14%	17%	21%	26%	30%
1 MW	850	9%	12%	15%	19%	22%	26%	30%

Daily energy demand was converted to annual energy demand (in megawatt-hours, or MWh) using a factor of 365.

Megawatt-hours were converted to British thermal units (Btu) at a rate of 3,413 MWh/Btu.

Table II.6 - Energy Demand at Charging Sites (Scenario 1)

	2029	2030	2031	2032	2033	2034	2035+
Daily (MW)	180	491	641	801	969	1,142	1,326
Annual (1,000 MW)	66	179	234	292	354	417	484
Annual (mmBtu)	224,000	611,000	799,000	998,000	1,207,000	1,423,000	1,652,000

Separate emission rates (grams per mile) were applied for medium-duty (class 50) and heavy-duty (class 60) trucks. Emission rates were used along with energy rates in mmBtu of energy per mile driven for internal combustion engine (ICE) vehicles and electric vehicles (ZEV). Emission and energy consumption rates per mile driven are shown in Table II.7 and Table II.8 for five-year increments. Emission rates for electricity generation are shown in Table II.9 in grams per million BTU.

Table II.7 – Mobile Source Emission Rates (g/mi)

	2025	2030	2035	2040	2045	2050
Class 50						
NOx	1.16	0.75	0.50	0.39	0.36	0.34
PM2.5	0.03	0.02	0.01	0.01	0.01	0.01
VOC	0.28	0.22	0.18	0.15	0.15	0.14
CO2e	945	885	849	829	817	810
Class 60						
NOx	3.30	2.11	1.42	1.13	1.02	0.97
PM2.5	0.05	0.02	0.01	0.00	0.00	0.00
VOC	0.15	0.11	0.08	0.07	0.07	0.07
CO2e	1,673	1,550	1,474	1,436	1,417	1,408

Table II.8 - Energy Consumption Rates (mmBtu/mi)

	2025	2030	2035	2040	2045	2050
Class 50 – ICE	0.0118	0.0110	0.0106	0.0103	0.0102	0.0101
Class 50 – ZEV	0.0038	0.0035	0.0037	0.0038	0.0038	0.0038
Class 60 – ICE	0.0206	0.0190	0.0180	0.0175	0.0173	0.0172
Class 60 – ZEV	0.0119	0.0120	0.0124	0.0127	0.0129	0.0130

Table II.9 - Emission Rates from Electricity Generation (g/mmBTU)

	2025	2030	2035	2040	2045	2050
NOx	31.14	24.60	20.09	16.51	13.69	11.12
PM2.5	14.34	13.06	12.41	11.94	11.46	11.04
VOC	12.58	12.30	11.78	11.22	11.11	11.02
CO2e	40,714	25,034	18,005	12,236	5,853	319

Energy rates for ZEVs (mmBtu/mile) were applied to total charging demand (mmBTU) to estimate ZEV VMT for medium and heavy trucks. Total energy demand was proportioned into medium and heavy truck energy demand based on (1) respective shares of truck stock per ACT projections, (2) average VMT per vehicle from the Annual Energy Outlook 2023 Reference Case, and (3) energy per mile for ICE medium and heavy trucks as shown above. Assumptions are shown in Table II.10 for stock, VMT per vehicle, energy shares, converted VMT, and the equivalent number of electric trucks displacing conventional fuel trucks. The equivalent number of electric trucks served is based on the converted VMT and the average VMT per vehicle.

Electricity generation emissions were estimated by applying the generation rates to the total electrical energy demand.

Total emissions effects were reduced by 1 percent compared to the gross benefits of the charging sites, to account for the fact that about 1 percent of the project costs would be covered by federal tax incentives rather than CPRG grant funds ($100,000 federal incentive per charging site = $2,400,000).

Table II.10 - Truck Stock and Energy Shares and Converted VMT (Scenario 1)

	2025	2030	2035	2040	2045	2050
ACT EV Stock Projections						
Medium Truck	1%	7%	20%	33%	43%	49%
Heavy Truck	1%	5%	12%	18%	22%	24%
VMT per Vehicle						
Medium Truck	14,961	14,103	14,009	13,991	14,000	14,177
Heavy Truck	33,953	32,803	32,232	31,871	31,696	31,720

Energy Share						
Medium Truck	20.1%	25.5%	28.8%	31.6%	33.1%	34.6%
Heavy Truck	79.9%	74.5%	71.2%	68.4%	66.9%	65.4%
Converted VMT (millions)						
Medium Truck	--	44.4	130.1	139.1	144.1	150.1
Heavy Truck	--	37.8	95.2	89.0	85.7	82.9
Total		82.2	225.3	228.1	229.8	233.0
Equivalent E-Trucks on Road						
Medium Truck	--	3,151	9,289	9,946	10,292	10,587
Heavy Truck	--	1,152	2,954	2,791	2,705	2,613
Total	--	4,302	12,243	12,737	12,997	13,200

Emissions benefits from off-corridor charging are calculated assuming that 25 percent of truck charging demands are met by public charging (overnight and fast charging), and the remainder by depot charging, based on ICCT (2021). The on-corridor emissions benefit associated with the installed public charging infrastructure is therefore assumed to be 25 percent of the total benefits, with off-corridor benefits being the remaining 75 percent or three times the on-site benefits as calculated based on energy supplied by the public chargers developed using CPRG funding. See the main workplan narrative for further context and explanation (Section 1.3., Demonstration of Funding Need).

Emissions from electricity generation units (EGU), refineries and other upstream emissions are not included in this analysis, which focuses on tailpipe emissions from freight trucks traveling through communities along the C3 corridor. Relatedly, U.S. EPA does not account for non-tailpipe emissions when showing compliance with heavy-duty vehicle Phase 3 GHG emissions standards, which the proposed ZE-MHDV charging infrastructure would directly support (see Section 1.3, Demonstration of Funding Need). Additionally, EGU emissions in the coalition states are capped by the declining limits set under the Regional Greenhouse Gas Initiative (RGGI) and therefore increases in electricity demand are not expected to substantially increase emissions from EGUs operating in C3 coalition states.

A.6 Reference Case Scenario

The total emissions from the freight trucks that would be converted from petroleum fuels to electricity as a result of the proposed ZE-MHDV charging infrastructure (as reflected in Tables 4 and 5 of the main workplan narrative), would be the baseline emissions for the population of vehicles affected.

For comparison, emissions from all mobile sources in the counties covering the proposed corridors totaled 1,845 tons of PM2.5 and 48,500 tons of NOx, as reported in the 2020 National Emissions Inventory and analyzed by Cambridge Systematics.

A.7 Measure-Specific Activity Data and Implementation Tracking Metrics

Number of sites built and charging ports activated by power level.

Charging station utilization and energy supplied.

Electric truck conversion in the participating states, as measured through registrations and/or vehicle incentives used.

Estimated GHG and criteria pollutant emission reductions based on energy supplied.

A.8 GHG and Co-Pollutant Emissions Reduced

Scenario 1: 50 percent of grid upgrade costs covered:

Table II.11 - GHG Reductions (metric tons CO2e), Scenario 1

	2025 - 2030	2025 – 2050
Benefits from on-corridor charging	115,000	4,643,000
Benefits from off-corridor charging	344,000	13,930,000
Total Benefits (reductions in mobile source emissions)	**459,000**	**18,574,000**
Electricity generation emissions	73,000	1,391,000
Net GHG reductions including electricity generation	**387,000**	**17,183,000**

Table II.12 - Reduction of Other Air Pollutants in 2030, Scenario 1

	NOx	PM2.5	VOC
Benefits from on-corridor charging (tons)	111.6	1.5	13.5
Benefits from off-corridor charging (tons)	334.8	4.4	40.4
Total reductions in mobile source emissions (tons)	446.4	5.8	53.9
Electricity generation emissions (tons)	59.5	31.6	29.8

Scenario 2: 100 percent of grid upgrade costs covered by C3 grant funding, conservatively assuming that site hosts cover none of the necessary costs associated with grid upgrades.

Table II.13 - GHG Reductions (metric tons CO2e), Scenario 2

	2025 - 2030	2025 - 2050
Benefits from on-corridor charging	90,000	3,641,000
Benefits from off-corridor charging	270,000	10,929,000
Total Benefits (reductions in mobile source emissions)	**360,000**	**14,572,000**
Electricity generation emissions	57,000	1,091,000
Net reductions including electricity generation	**303,000**	**13,480,000**

Table II.14 - Reduction of Other Air Pollutants in 2030, Scenario 2

	NOx	PM2.5	VOC
Benefits from on-corridor charging (tons)	87.5	1.1	10.6
Benefits from off-corridor charging (tons)	262.4	3.4	31.7
Total reductions in mobile source emissions (tons)	349.9	4.6	42.2
Electricity generation emissions (tons)	46.7	24.8	23.3

A.9 Corridor Definition and Methodology for and LIDAC Analysis

For the purposes of the LIDAC analysis, this measure is assumed to provide benefits to communities located in close proximity to the I-95 corridor and adjacent roadways along which future charging sites could be developed with funding awarded to the C3 proposal. This approach was taken based on the understanding that reductions in CAP and HAP emissions that result from freight truck electrification would provide the most direct health benefits to these same communities.

The first step to this analysis was to define the I-95 corridor and adjacent freight corridors that are located in the coalition member states. As a starting point, the coalition identified freight corridor segments that were identified as Phase 1 priorities by the National ZEF Strategy. Then these highway segments were selected using the FHWA's National Highway System (NHS) roadway layer in ArcGIS.

Table II.15 – Interstate Highways that Define the C3 Corridor Region, and LIDAC Analysis for the Proposed Measure

C3 Corridors	CT	DE	MD	NJ
Interstate highways	I-84 (NE of Hartford) I-91 I-95 (W of New Haven)	I-95 I-295 I-495	I-95 I-495 I-695 I-895	I-95 & NJ Turnpike I-295 (S of exit 47) I-287 I-80 I-280 I-78

The second step of this analysis was to identify LIDAC communities that are directly adjacent to the corridor or are otherwise in close-enough proximity to realize the benefits of pollution reduction along the freight corridor. This involved using two separate screening criteria, as follows:

1. Adjacent communities: Adjacent communities are defined as any LIDAC Census Block Groups – classified as Disadvantaged in the EPA IRA Disadvantaged Communities ArcGIS layer – that are adjacent to the freight corridors identified for this project. To determine which communities are adjacent, ArcGIS was used to identify any LIDAC Census Block that is within 100 meters on either side of the corridor. This 200 meter "buffer zone" was used because the corridor is a simple line in the FHWA NHS ArcGIS file, while, in reality the highway right of way is much wider. So, we used this buffer to be sure we were capturing all adjacent Census blocks using the ArcGIS tool.

2.Traffic Proximity communities: The second approach was to use ArcGIS to identify any Census block groups that are within 500 meters on either side of the corridor that have an EJScreen Traffic Proximity Supplemental Index of 90th percentile or above, as derived from the EJScreen US Percentiles Block Groups ArcGIS layer. This distance was used because the methodology for identifying communities using this supplemental index applies to Census block groups within 500 meters of highways.

Figure II.1 illustrates examples of the LIDAC analysis being applied to Wilmington, DE, and Newark, NJ.

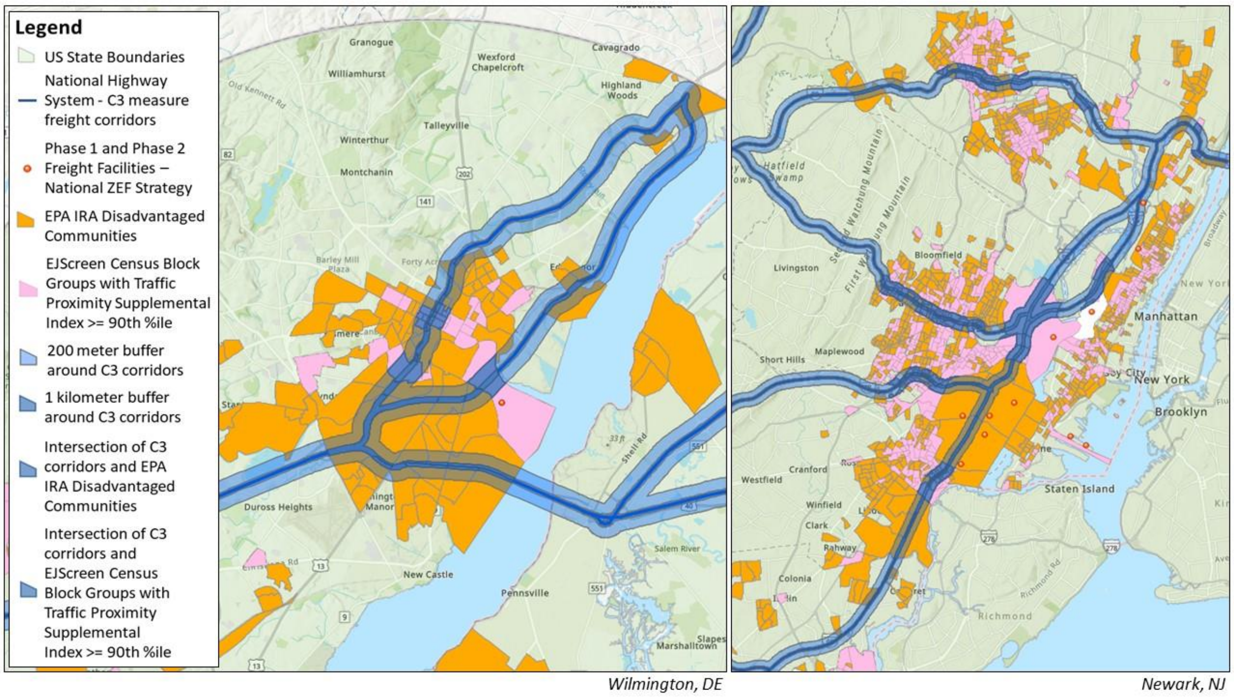

Figure II.1: Illustration of LIDAC analysis being applied in two metropolitan areas.

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