**IMPLEMENTATION GRANT APPLICATION 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 the Arkansas and Oklahoma Clean Transportation Connection proposal. The “GHG Emission Reduction Calculation Spreadsheet” included with this application provides the specific GHG emission reduction calculations for this proposal.

1. Emission Reduction Estimate Method:

Argonne Laboratory Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool background data and formulas were used to estimate reductions in GHG emissions, and air pollutant emissions from replacing heavy-duty diesel vehicles will fuel cell and battery electric equivalents. The AFLEET CFI tool was used to estimate reductions from infrastructure. These tools are available for download at <https://afleet.es.anl.gov/home/>.

1. Models/Tools Used:

The AFLEET Tool 2023 background data and tool formulas were used to derive the emission factors used to estimate GHG and vehicle operation air pollutant emissions for replacing heavy-duty diesel vehicles with battery electric and fuel cell equivalents. The background data from this tool was also used to estimate costs of heavy-duty battery electric vehicles.

AFLEET CFI Tool was used to estimate emission reductions associated with the installation and operation of heavy-duty hydrogen fueling and electric vehicle charging infrastructure. The following input assumptions were used to run the tool:

* Moderate utilization
* 100% heavy duty
* Source of Electricity for EVSEs and Hydrogen: Region 9
* Hydrogen production process: natural gas steam methane reformation

Both tools were developed by the Argonne National Laboratory. The tools use data from Argonne’s Research and Development Greenhouse Gases, Regulated Emissions, and Energy use in Technologies (GREET) fuel-cycle model and the United States Environmental Protection Agency’s (EPA’s) Motor Vehicle Emissions Simulator (MOVES) and certification data.

1. Measure Implementation Assumptions:

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

* Measure Uptake
  + The heavy-duty hydrogen fueling and electric vehicle charging infrastructure competition is a one-time opportunity and is fully subscribed
  + The heavy-duty diesel replacement competition is a one-time opportunity and is fully subscribed
* Implementation Milestones
  + Both competitions solicit proposals in early 2025
  + Infrastructure and vehicle replacement projects are selected summer 2025
  + Vehicle replacement projects are complete, replaced diesels have been scrapped, and fuel cell and battery electric equivalents are in fleet use by summer 2027
  + Subaward amounts for the heavy-duty diesel replacement competition will not exceed the vehicle costs after tax incentives have been incorporated
  + Infrastructure projects are complete and operational by summer 2027 (two years to procure and install hydrogen fueling and electric charging equipment)
* Measure lifetime
  + Average lifetime for hydrogen and electric vehicle infrastructure is assumed to be 30 years to match maximum vehicle lifetime consistent with AFLEET Tool 2023 background data
  + Average heavy truck lifetime is assumed to be 28 years consistent with AFLEET Tool 2023 background data
* Cost assumptions:
  + Heavy-Duty Battery Electric Vehicle Charging
    - Data submitted to the coalition by truck stop operators with recent experience installing and operating electric vehicle supply equipment (EVSE) for heavy-duty transportation applications indicate their typical costs for a site with four 350 kW direct current fast charging (DCFC) EVSEs are between $2.5 and $3.5 million. [[1]](#footnote-2)For the purposes of this analysis, a cost of $3.5 million per site was assumed.
    - For reference, publicly available data indicate the following EVSE cost per unit (2022$ basis) for 350 kW direct current (DC) fast charging: [[2]](#footnote-3)
      * Capital cost: $277,200
        + Hardware: $139,000
        + Elect. Materials: $500
        + Other Materials: $500
        + Electrician Labor: $2500
        + Other Labor: $14,000
        + Mobilization: $1,000
        + Permitting: $200
        + Transformer: $119,500
      * Annual operation and maintenance: $98,287
  + Heavy-Duty Hydrogen Refueling
    - Data submitted to the coalition by truck stop operators with recent experience installing and operating liquid hydrogen refueling stations for heavy-duty transportation applications indicate their typical costs for a liquid hydrogen site with one tank and two dispensers range between $10 and $14 million.[[3]](#footnote-4) For the purpose of this analysis, a cost of $14 million per site was assumed.
    - For reference, publicly available estimates (2016$ basis) for 350 bar Cryo-pump dispensing liquid hydrogen station (per unit) indicate the following costs for a similar site:[[4]](#footnote-5)
      * Capital cost: $4,354,244
        + Low production volume assumed for cost-estimates
        + Annual Average Daily dispensing rate per day (kg/day): 7000
        + 2 Dispensers
        + 10,720 kg liquid hydrogen cryogenic storage tank
      * Annual Operation and maintenance: $553,978
  + Class 8 Combination Long-Haul Trucks (2022$ basis) were consistently obtained from private fleet contacts were consistent with publicly available data from the AFLEET tool, with the exception of hydrogen fuel cell vehicles. Hydrogen fuel cell capital cost data was obtained from an original equipment manufacturer.[[5]](#footnote-6)
    - Capital cost based on heavy-duty fuel type
      * Diesel: $150,000
      * Hydrogen Fuel Cell: $675,000
      * Battery Electric: $850,000
    - Annual Maintenance and Repair Costs:
      * Diesel: $0.18/mile
      * Hydrogen Fuel Cell: $0.15/mile
      * Battery Electric: $0.15/mile
  + Tax credits:
    - Federal tax credit for qualified alternative fuel vehicle refueling depreciable property: 30% the cost of the qualified property placed in service during the previous tax year, up to $100,000 per item[[6]](#footnote-7)
    - Federal tax credit for commercial electric vehicles and fuel cell electric vehicles: the lesser of 30% of the vehicle purchase price or the incremental cost of the vehicle compared to an equivalent internal combustion engine vehicle ($40,000 maximum credit for vehicles above 14,000 lbs)
    - Oklahoma tax credit: 45% of the cost of installing commercial alternative fueling infrastructure[[7]](#footnote-8)
    - Oklahoma tax credit for fuel cell vehicles in excess of 26,501 pounds: 100,000[[8]](#footnote-9)

1. Measure Implementation Assumptions:

For these calculations, class 8 combination long-haul trucks with an annual mileage of 170,000 per year that would be replaced under this program were assumed to be 15 years old (engine model year 2012) at the time of replacement with 13 years of remaining life based on the AFLEET 2023 assumed years of LDV and HDV ownership.[[9]](#footnote-10)

Based on these assumptions, the following emission factors were used to quantify emission reductions from the heavy-duty vehicle diesel to zero-tailpipe- emissions replacement competition:

|  |  |  |  |
| --- | --- | --- | --- |
| Pollutant | Class 8 Combination Long-Haul Truck Emission Factors (g/mi) | | |
| 2012 Diesel | New Fuel Cell | New Battery Electric |
| Carbon monoxide | 3.377 | 0 | 0 |
| Nitrogen oxides | 4.125 | 0 | 0 |
| Coarse particulate matter (PM10) | 0.029 | 0 | 0 |
| Fine particulate (PM2.5) | 0.026 | 0 | 0 |
| Volatile organic compounds (VOC) | 0.114 | 0 | 0 |

The region-specific emission factor for electricity for transportation use is 468 grams of CO2e per kWh for the AFLEET SPP region (Region 9).[[10]](#footnote-11)

The diesel emission factor is 12,489 grams CO2e per gallon [[11]](#footnote-12)

The hydrogen fueling emission factor is 4 kg CO2e per kg of hydrogen.[[12]](#footnote-13)

1. Reference case scenario:

According to the 2020 national emissions inventory, Class 8 long-haul combination trucks emit 6,282,019.97 mt CO2e per year in Oklahoma and Arkansas.[[13]](#footnote-14)

1. Measure-Specific Activity Data and Implementation Tracking Metrics:

This analysis assumes that three heavy-duty hydrogen fueling and electric vehicle charging sites are funded and operational by July 1, 2027. Each site will include:

* Four 350 kW DC fast-charging EVSEs
* Two hydrogen refueling lanes and one tank

This analysis assumes that fifty 2012 engine model year class 8 combination long haul trucks diesel trucks with an annual mileage of 170,000 are replaced with 25 fuel cell electric vehicle and 25 battery electric equivalents by 2027.

This analysis also assumes a moderate usage of installed hydrogen refueling and DCFC charging that results in additive emission reductions to the vehicle replacement competition.

Tracking metrics will include:

* Make, model, vehicle identification number, and engine model year of each diesel vehicle being replaced
* Make, model, and engine model year for each replacement zero-tailpipe-emission vehicle
* Hydrogen refueling stations installed
* DC fast charging EVSEs installed

1. GHG and Co-Pollutant Emission Reductions

Implementation of this measure is anticipated to reduce 5,934 mtCO2e in 2026 and 11,867 mtCO2e each year thereafter, with 41,536 cumulative mtCO2e for the period between 2025 – 2030 and 278,884 cumulative mtCO2e for the period between 2025 – 2050. These annual and cumulative GHG emission reduction values represent emission reductions achieved attributable to CPRG implementation dollars consistent with the following formula:

Quantified GHG reductions from CPRG funding = [(Requested CPRG funding)/(Total

funding to implement measure)] x (Total estimated GHG reductions of measure)

Annual co-pollutant benefits associated with the implementation of this measure are listed in the table below.

|  |  |
| --- | --- |
| Pollutant | Tons Reduced |
| Carbon monoxide | 34 |
| Nitrogen oxides | 42 |
| Coarse particulate matter (PM10) | 0 |
| Fine particulate (PM2.5) | 0 |
| Volatile organic compounds (VOC) | 1 |

1. Cost data was provided on condition of anonymity. [↑](#footnote-ref-2)
2. AFLEET Tool 2023, Background Data rows 1331 – 1370. [↑](#footnote-ref-3)
3. Cost data was provided on condition of anonymity. [↑](#footnote-ref-4)
4. Cost assumptions calculated with the Argonne National Laboratory Heavy Duty Refueling Station Analysis Model (HDRSAM)HDRSAM Version 1.0 tool [↑](#footnote-ref-5)
5. AFLEET Tool 2023, Background Data rows 41-44 [↑](#footnote-ref-6)
6. Alternative Fuel Infrastructure Tax Credit, installation assumed to meet U.S. Department of Labor prevailing wage and apprenticeship requirements. [↑](#footnote-ref-7)
7. Oklahoma Statutes – §68-2357.22 B.3 and D.2. [↑](#footnote-ref-8)
8. Oklahoma Statutes – §68-2357.22 B.5. and D.1.d. [↑](#footnote-ref-9)
9. AFLEET 2023, Background Data, rows 1225 and 1226 [↑](#footnote-ref-10)
10. AFLEET 2023, 'Background Data'!$N$1789/10^6\*'Background Data'!$C$1907 [↑](#footnote-ref-11)
11. AFLEET 2023, 'Background Data'!$J$1789/10^6\*'Background Data'!$C$1898 [↑](#footnote-ref-12)
12. Hydrogen production was assumed to be produced offsite by steam methane reformation with carbon capture meeting the Section 45V tax credit definition of clean hydrogen with 4 kg CO2e per kg of hydrogen. [↑](#footnote-ref-13)
13. EPA’s 2020 NEI Data Retrieval Tool was accessed and county-level GHG data was downloaded on March 5, 2024. <https://awsedap.epa.gov/public/single/?appid=20230c40-026d-494e-903f-3f112761a208&sheet=5d3fdda7-14bc-4284-a9bb-cfd856b9348d&opt=ctxmenu,currsel> [↑](#footnote-ref-14)