1.0 INTRODUCTION

The Technical Appendix (TA) provides a detailed summary of the data inputs, reference sources, and methodologies in quantifying greenhouse gas (GHG) and co-pollutant emissions reductions for the Montana Department of Natural Resources and Conservation (DNRC) implementation grant application. This is in support of implementation grants funding opportunity developed for the U.S. Environmental Protection Agency's (EPA) Climate Pollution Reduction Grant (CPRG) program.

The application contains the following priority reduction measures and estimated greenhouse gas (GHG) emissions reduction in Table 1-1 and Table 1-2.

Table 1-1: Estimate Greenhouse Gas Reduction Potential and Cost Effectiveness by Measure

Measure No.	Measure	Requested CPRG Funding	Cumulative GHG Emission Reductions (MMT CO_2e)		Cost Effectivenes $/MT CO_2e
			By 2030	By 2050	2025 - 2030
1	School Energy Performance Initiatives	$ 24,595,948	0.011	0.065	$ 2,225
2	Conversion of Fleet Vehicles to Cleaner Fuels	$ 10,369,695	0.0035	0.0138	$ 2,948
3	Investments in Electric Grid Technology	$ 11,983,832	0.02	0.16	$ 494
TOTAL		$ 48,949,475	0.039	0.237	$ 1,260
4	Commercial Energy Efficiency Measures (C-PACE Audits)	$ 2,000,000	Enabling Measure		

Table 1-2: Estimate Greenhouse Gas Reduction Potential and Cost Effectiveness by Measure

Measure No.	Measure	Emissions Reduction by 2030							
		PM_{10}	$PM_{2.5}$	SO_2	NOx	CO	VOC	Pb	HAPs
		tons	tons	tons	tons	tons	tons	tons	lbs
1	School Energy Performance Initiatives	0.52	0.48	2.14	5.91	2.85	0.23	9.78E-06	79.69
2	Conversion of Fleet Vehicles to Cleaner Fuels	1.67	1.27	-0.66	48.10	1.66	3.64	--	--
3	Investments in Electric Grid Technology	1.80	1.53	8.85	14.91	0.03	0.48	--	--
TOTAL		3.99	3.28	10.33	68.91	4.54	4.35	9.78E-06	79.69
4	Commercial Energy Efficiency Measures (C-PACE Audits)	Enabling Measure							

The Workplan included with the implementation grant application provides a detailed overview of each measure along with supporting information, such as including key implementing agencies, implementation schedules and milestones, geographic scope, metrics for tracking progress, funding, and impacts on low-income and disadvantaged communities. The primary focus of the TA is to describe the methodology in quantifying GHG and co-pollutant reductions for each measure through 2030 and 2050. The calculations quantifying emissions reduction for all measures, along with additional discussion of the methodology, is included as an attachment to the Technical Appendix titled, Attachment 1: Emissions Reduction Calculations Spreadsheet.

2.0 OVERALL APPROACH AND METHODOLOGY

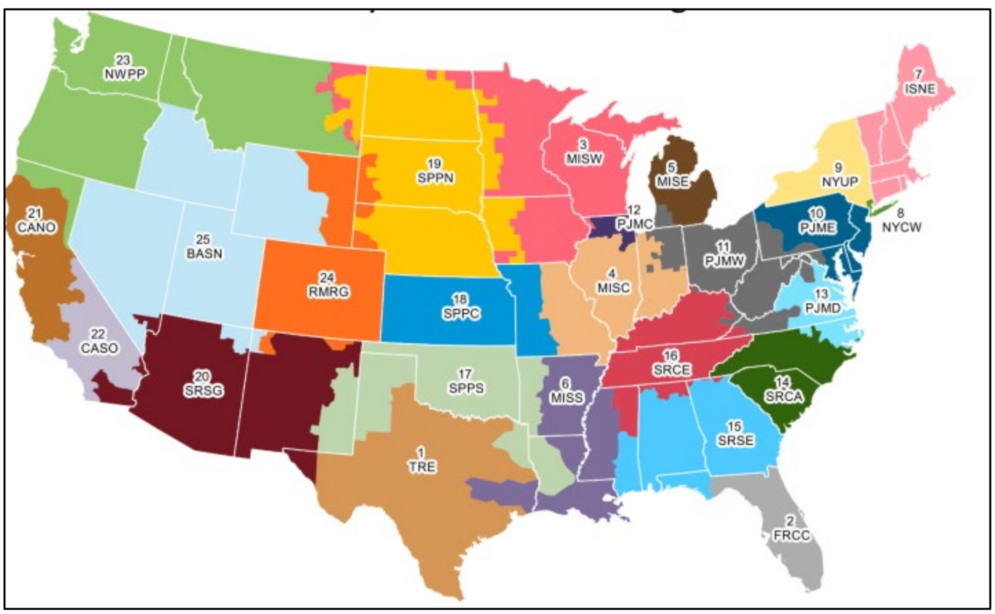
The emissions reduction potential quantified for each priority measure is an extension of the calculations preformed for the Priority Climate Action Plan (PCAP). For the purposes of the PCAP, an overall unitized approach was evaluated for each measure when program-specific inputs were not yet determined. This provided a scalable basis for future reduction and implementation considerations to be used for the implementation grant process. The sectors evaluated within the PCAP exist within a complex and interdependent system where reduction in one sector can change the conditions for evaluating other sectors. This evaluation acknowledges the complexity in those systems but evaluated reduction potential for each measure independently of each other.

3.0 PROJECTING EMISSIONS REDUCTION

3.1 Electricity Grid Decarbonization Considerations

Scaling emissions reduction potential to 2030 and 2050 requires projecting the future carbon intensity of electrical generation. For measures that rely on these considerations, the future carbon intensity of grid-scale electricity production relied on the Annual Energy Outlook 2023 (AEO2023) Issues in Focus: Inflation Reduction Act Cases in the AEO2023 (EIA2023) analysis published by the U.S. Energy Information Administration (EIA). This evaluates potential results of implementing the laws and regulations of the Inflation Reduction Act (IRA) and projects future electricity generation in billions of kilowatt hours (BkWh) and corresponding emissions of carbon dioxide (CO_2) in millions of short tons. The trends provided in AEO2023 are scaled and utilized in the analysis to determine the future carbon intensity of electricity use when quantifying emissions reduction totals by 2030 and 2050. Figure 1 shows the electricity market module regions for Montana.

Figure 3-1: Electricity Market Module Regions



Data for the three regions in Montana were gathered to assess the anticipated reduction in carbon intensity through 2050. AEO2023 quantifies four different use cases dependent upon to uptake of financial incentive opportunities through the Inflation Reduction Act (IRA). AEO2023 forecast the reduction in grid carbon intensity along with the forecast energy generation requirements given no IRA, high uptake of the IRA, low uptake of the

IRA, and a reference case of anticipated uptake. The following figures show these four trends for each electricity market module region included in the assessment for Montana's future gird carbon intensity.

Figure 3-2: NWPP – WECC/Northwest Power Pool

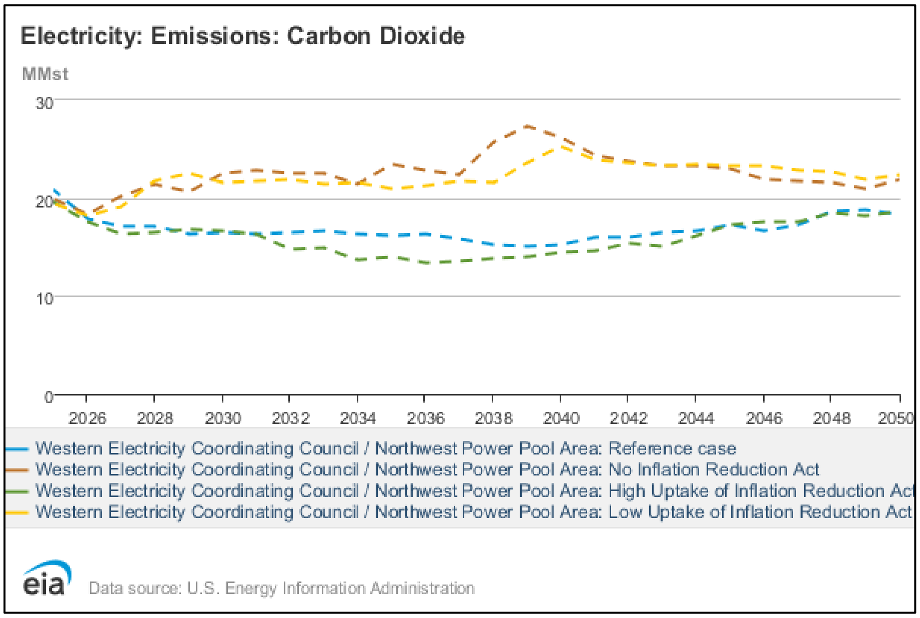


Figure 3-2: NPPN – Southwest Power Pool/North

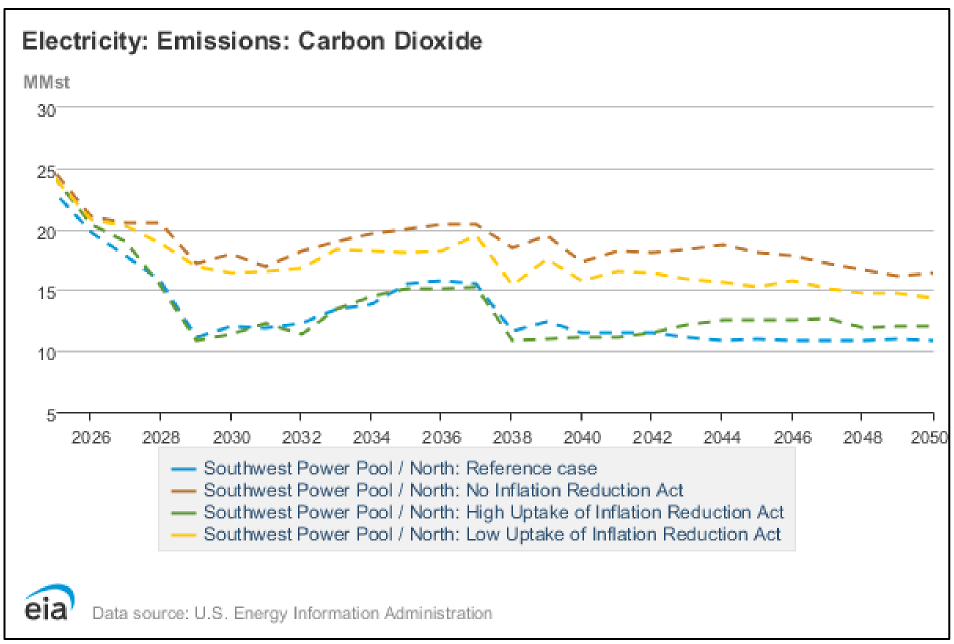
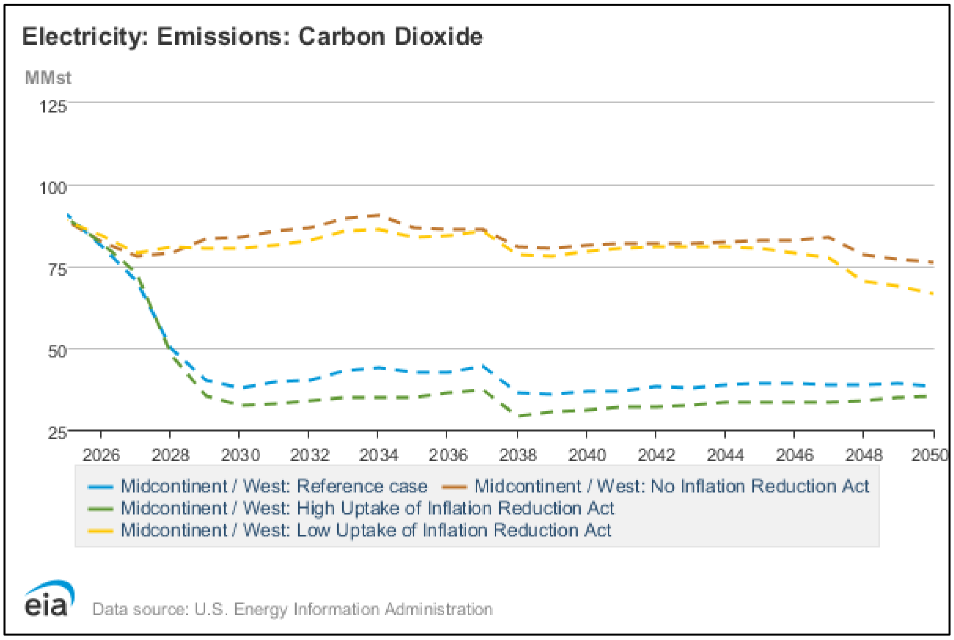


Figure 3-3: MISW – Midcontinent ISO/West



The anticipated total electricity generation and GHG emissions per year are totaled for the service area and an individual carbon intensity factor is calculated for each year, 2025 to 2050. The carbon intensity factor is then formulated as a percentage of the 2025 carbon intensity. Annualized emissions are calculated for each measure in 2025. Applying the year-specific carbon intensity factor for subsequent years then provides reduction potentials based on the anticipated decarbonization of the electrical grid from 2025 – 2050. These calculations and methodology are included in Attachment 1: Emissions Reduction Calculations Spreadsheet.

3.2 Renewable Energy Source Degradation Considerations

Similarly, scaling emissions reduction potential to 2030 and 2050 requires accounting for the degradation of renewable energy sources over their equipment lifespan. The TA analysis accounts for published degradation factors for the following renewable energy sources:

Utility-Scale Solar

- Factor: 0.5% average degradation per year
- Reference: NREL2018

Utility-Scale Onshore Wind

- Factor: 0.63% average degradation per year
- Reference: Astolfi et al. 2022

These calculations and methodology are also included in Attachment 1: Emissions Reduction Calculations Spreadsheet.

4.0 INCENTIVIZE SCHOOL ENERGY PERFORMANCE MEASURES

4.1 Measure 1: School Energy Performance Initiatives

a. Emission Reductions Estimate Method:

Montana's school buildings are diverse in age, size, student population, geography, and fuel use. It is challenging to predict a specific and comprehensive list of energy conservation measures required to fulfill this measure due to the potential variability of the applicant pool. Therefore, the quantification methodology references recent Investment Grade Audits (IGAs) of Montana K-12 school building stock to provide a realistic summary of building upgrades. All IGA's were conducted by qualified Energy Service Companies (ESCOs) through the MDEQ Energy Performance Contracting program. Therefore, the audits, analysis, and proposed measures adhere to the energy development and conservation program requirements listed in Montana Code Annotated Title 90, Chapter 4, Part 11.

The summary of six IGAs is includes in Attachment 1 and represents school districts of varying student population, geography, climate, and utility providers. This aggregation of data provides a representation of the potential applicant pool for an implemented program with variation in all categories that are representative of the state. The IGA data also provides realistic project costs that include additional infrastructure considerations for retrofit projects, such as HVAC ventilation mechanical replacements and electrical single phase protection upgrades. The following table provides results of the IGA review.

A variety of energy conservation measures (ECMs) were evaluated within the IGAs and selected for each project depending upon the existing condition of the schools, the existing fuel type, and utility costs. All projects generally utilized similar technology for lighting upgrades, weatherization, and retro-commissioning. The largest potential variance occurs for HVAC upgrades, so projects were selected to provide a variety of HVAC retrofit options, including replacing steam boilers with new condensing hot water boilers, installing a condensing boiler with a dedicated outdoor air system, and fuel switching to full electrification with air source heat pumps and electric resistance heating. Projects also considered solar PV installations and EV charging infrastructure. The ECM table in Attachment 1 summarizes the ECMs selected for each project evaluated along with the estimated total annual energy conserved for all fuel types.

The measure also identifies on-site power generation as a potential inclusion within projects. Therefore, the analysis also evaluated the reduction potential of including on-site solar PV systems with each energy efficiency upgrade project. The majority utility in Montana provides a net metering opportunity for solar PV systems that are 50-kW or less. Therefore, this analysis considers the measure providing an opportunity to install a 50-kW solar PV system at each school. Emissions reduction for solar PV systems were quantified using the EPA Avert Tool. It considered (12) 50-kW solar PV installs. On-site solar PV reduction potential was evaluated using the EPA AVERT Tool for varying total MW-contributions to the grid. The selected geography was the State of Montana and distributed solar PV total capacity was input.

b. Models/Tools Used:

Existing investment grade audit (IGA) data and reports for Montana schools were used to provide reference evaluations for energy conservation measure projects. The AVERT tool was used to calculated emissions reduction from on-site solar PV installations.

c. Measure Implementation Assumptions:

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

- Implementation measure uptake
  - The measure supports existing energy efficiency upgrade programs within Montana DEQ. Measure implementation would be required program development, administration, and outreach during Year 1. The emissions reduction potential accounts for (6) project to be achieving emissions reduction in Year 2 of the program with the other (6) projects achieving reduction in Year 3.
- Implementation milestones
  - (6) projects in year 2 and year 3 (12 projects total)
  - Includes weatherization, lighting, controls, and HVAC upgrades
  - Also includes a 50-kW solar PV system installation with each project (12 total)
- Measure lifetime
  - Service life for energy efficiency equipment upgrades can vary depending on the energy conservation measure and equipment. Hot water heating and HVAC equipment can have an anticipated service life of 12-15 years while LED lighting equipment can have an anticipated service life of 25+ years depending on usage rates. An average service life of 20-years was applied to all the building upgrade measures to account for this variability between ECMs.
  - A service life of 25+ years is applied to the solar PV systems however a degradation rate is applied over time at 0.05% per year.
- Capital cost and operation and maintenance cost assumptions
  - Costs associated with measure implementation are based on known project costs and resultant energy conservation through the IGA data aggregation. A portion of funding is set aside for solar PV installs based on recent solar cost for Montana DEQ projects. The remaining funds are then scaled to estimate energy conservation and emissions reduction based on IGA data. This is shown in Attachment 1.

d. Emission Reduction Estimate Assumptions:

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

- Emission rates, factors, model inputs
  - Emission reduction estimated for energy efficiency measures are built upon known IGA evaluations of Montana schools. Solar PV emissions reduction estimates are calculated using the AVERT tool. Changes in grid carbon intensity over 25-years is accounted for based on AEO2023 inputs from Section 3.1, and solar degradation is accounted for as detailed in Section 3.2. All calculations for the measure are included in Attachment 1.

e. Reference Case Scenario:

The reference case scenario accounts for the following:

- The reference case accounts for continued operation of the school building stock with existing mechanical equipment, energy efficiency ratings, and no solar PV.

5.0 CLEAN, RELIABLE TRANSPORTATION

Measure 2: Strategic Conversion of Fleet Vehicles to Cleaner Alternatives

a. Emission Reductions Estimate Method:

Annual emissions reduction potential is calculated using the Argonne National Lab (ANL) - Alternative fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool. Default values were selected for vehicle mileage and fuel economy and WECC was selected for the electricity source. The emission reductions quantified for the switcher locomotive engine were calculated using the US EPA's Diesel Emissions Quantifier "Emissions Results and Health Benefits for Project: Switcher Tier 4" guidance while the pushback and belt loader vehicle emissions are based on equivalent values from the 2020 GSE Emissions Inventory for the Los Angeles Airport, EPA AQMD Document. All calculations are included in Attachment 1 with additional information regarding methodology. Emission reductions are based on an anticipated distribution of funding by vehicle type; however, this will ultimately be determined by applicants.

a. Models/Tools Used:

ANL developed the AFLEET Tool to help stakeholders estimate petroleum use, greenhouse gas (GHG) emissions, air pollutant emissions, and cost of ownership of light-duty and heavy-duty vehicles. The analysis accounts for wells-to-wheels emissions for petroleum use, GHGs, and air pollutants. Additionally, the US EPA's Diesel Emissions Quantifier provides estimated emissions reduction for the upgraded Tier 4 diesel locomotive switcher engine.

b. Measure Implementation Assumptions:

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

- Implementation measure uptake
    - MDEQ's Energy Bureau has a successful zero emissions vehicle program based on the Volkswagen Diesel Emissions Settlement funding and Diesel Emissions Reduction Act (DERA) funding. Emission reduction calculations assumes purchase and vehicle delivery occur in Year 1 and full vehicle operation occurs over 4 years during the 2025 - 2030 period. Operation through the estimated lifetime of each vehicle dictates total emissions for the 2025-2050 period.
- Implementation milestones

    - Program implementation, project solicitation, and purchase of vehicles within the first year of funding. Emissions are based on funding approximately (26) total vehicle. Distribution of funds and purchased vehicle type will depend on applicants.
- Measure lifetime
    - Service life for BEVs depend on the type of vehicle and use case. The service life for each vehicle assessed in the analysis is included in Attachment 1 and dictates the quantity of emissions reduced through 2050.
    -
- Capital cost and operation and maintenance cost assumptions
    - Costs associated with measure implementation are based on known project costs through established program metrics and market familiarity. Anticipated vehicle costs and funding is shown in Attachment 1.

c. Emission Reduction Estimate Assumptions:

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

- Emission rates, factors, model inputs
    - Emission reduction estimates are based on the default factors and vehicle miles traveled (VMT) values in AFLEET or EPA's diesel emissions quantifier. Individual details for each vehicle are included in Attachment 1.

d. Reference Case Scenario:

The reference case scenario accounts for the following:

- The reference case accounts for continued operation of existing internal combustion engine vehicles.

6.0 INDUSTRIAL & POWER SECTOR INNOVATION

Measure 3. Investment and Improvement in Electric Grid Technology

e. Emission Reductions Estimate Method:

Adding capacity to the existing electrical grid is paramount to connect new renewable energy sources and reduce overall GHGs from all sectors requiring a large increase in electricity demand and usage. Requests to connect to the U.S. transmission grid grew by 40% in 2022, including nearly 2,000 GW of solar and energy storage resources. The amount of solar, wind, and storage in the current interconnect queues exceeds the amount needed to get to 90% of U.S. electricity from zero-carbon resources by 2035 (LBNL 2023). Additionally, adding further resilience to the existing grid is necessary to ensure the ongoing operation of critical care facilities and areas of refuge as more operations move towards electrification. The installation of microgrids provides on-site power generation and back-up to aid in this grid resiliency and provide redundancy to electricity applications as well.

This measure quantifies the installation of microgrids at the utility-scale as well as the local scale when places at critical care facilities. It also considers opportunities for reconductoring distribution feeder lines to increase capacity to connect lower carbon power generation projects to the grid or to fund a study that can assess potential for debottlenecking grid interconnection.

Microgrids for this measure only consider solar PV and battery energy storage systems (BESS). Emissions reduction from microgrids are quantified by amount of grid electricity they offset due to power generation and cycling and depth of discharge of battery storage. Emissions associated with distribution reconductoring are not quantified. It is expected that decreasing line loss will reduce grid emissions due to increased efficiency, however reconductoring also provides the opportunity to unlock more renewable energy sources to the grid.

f. Models/Tools Used:

The EPA AVERT tool was used to calculated emissions reduction from microgrid installations.

g. Measure Implementation Assumptions:

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

- Implementation measure uptake
  - MDEQ's Energy Bureau has an existing program for transmission resiliency funding due to the 40101(d) program. The analysis assumes construction and operation of all facilities is completed within first 2-years of funding period resulting in 3-years of total operation during the 2025-2030 period.
- Implementation milestones
  - Emissions are based on funding the equivalent of:
    - (2) Utility scale microgrid systems with 2 MW ground-mount solar PV and BESS rated at 2MW/2MWh.
    - (6) Critical care facility supporting microgrids with 131 kW roof mount solar PV and BESS rated at 75 kW/500 kWh
    - It also accounts for the funding of distribution reconductoring around ~2700 feet of feeder line or the cost to conduct a study on greater transmission reconductoring projects
- Measure lifetime
  - Service life for Solar PV systems is considered 25+ years but accounts for panel degradation at 0.5% per year. BESS battery systems are evaluated at a service life of 7 years based on 2300 cycles per year at an 80% depth of discharge.
- Capital cost and operation and maintenance cost assumptions
  - Costs associated with measure implementation are based on known project costs through local or equivalent projects. The utility scale microgrid cost is based on an equivalently sized project in Ravalli County Montana. The critical care facility microgrid sizing and cost is based on an equivalent project for a 911 emergency center. Reconductoring cost is based on "The Cost of Distribution System Upgrades to Accommodate Increasing Penetrations of Distributed Photovoltaic Systems on Real Feeders in the United States" Horowitz et al, 2018 (NREL 2018).
  - The cost of equivalent projects dictates the number of estimated installations and system sizes.

h. Emission Reduction Estimate Assumptions:

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

- Emission rates, factors, model inputs

- Existing data from equivalent projects is used to assess emissions reduction potential. Individual details for each microgrid project are included in Attachment 1.

i. Reference Case Scenario:

The reference case scenario accounts for the following:

- The reference case accounts for continued operation utilizing only grid tied electricity.

REFERENCES

Astolfi et al. 2022. *Data-Driven Assessment of Wind Turbine Performance Decline with Age and Interpretation Based on Comparative Test Case Analysis*.

EIA. 2023. *AEO2023 Issues in Focus: Inflation Reduction Act Cases in the AEO2023*. Washington, DC: Energy Information Administration, U.S. Department of Energy.

LBNL 2023. Lawrence Berkley National Laboratory (LBNL). *Grid connection requests grow by 40% in 2022 as clean energy surges, despite backlogs and uncertainty*. https://emp.lbl.gov/news/grid-connection-requests-grow-40-2022

NREL 2018. “The Cost of Distribution System Upgrades to Accommodate Increasing Penetrations of Distributed Photovoltaic Systems on Real Feeders in the United States” Horowitz et al, 2018 (NREL 2018).

NREL 2018. *STAT FAQs Part 2: Lifetime of PV Panels*. Washington, DC: National Renewable Energy Laboratory, U.S. Department of Energy.

Montana Climate Pollution Reduction Grant
Implementation Grant Application
Attachment 1: Emissions Reduction Calculations Spreadsheet

GHG Emission Reduction

Measure No.	Measure	Requested CPRG Funding	Cumulative GHG Emission Reductions (MMT CO_2e)		Cost Effectiveness $/MT CO_2e
			By 2030	By 2050	2025 - 2030
1	School Energy Performance Initiatives	$ 24,595,948	0.011	0.065	$ 2,225
2	Conversion of Fleet Vehicles to Cleaner Fuels	$ 10,369,695	0.0035	0.0138	$ 2,948
3	Investments in Electric Grid Technology	$ 11,983,832	0.02	0.16	$ 494
TOTAL		$ 48,949,475	0.039	0.237	$ 1,260
4	Commercial Energy Efficiency Measures (C-PACE Audits)	$ 2,000,000	Enabling Measure		

Criteria Pollutants and HAPs Reduction

Measure No.	Measure	Emissions Reduction by 2030							
		PM_{10}	$PM_{2.5}$	SO_2	NOx	CO	VOC	Pb	HAPs
		tons	tons	tons	tons	tons	tons	tons	lbs
1	School Energy Performance Initiatives	0.52	0.48	2.14	5.91	2.85	0.23	9.78E-06	79.69
2	Conversion of Fleet Vehicles to Cleaner Fuels	1.67	1.27	-0.66	48.10	1.66	3.64	--	--
3	Investments in Electric Grid Technology	1.80	1.53	8.85	14.91	0.03	0.48	--	--
TOTAL		3.99	3.28	10.33	68.91	4.54	4.35	9.78E-06	79.69
4	Commercial Energy Efficiency Measures (C-PACE Audits)	Enabling Measure							

Montana Climate Pollution Reduction Grant
Implementation Grant Application
Attachment 1: Emissions Reduction Calculations Spreadsheet

Measure: School Energy Performance Initiatives
Greenhouse Gas Emissions Calculations

References
Energy Efficiency and Retrofit Projects: Existing Investment Grade Audits - Montana School Districts
Solar PV Projects: AVERT Tool

Summary of GHG Emissions Reductions

Priority Measure	Cumulative GHG Emission (MMT CO_2e)		Cost Effectiveness $/MT CO_2e
	By 2030	By 2050	2025 - 2030
School Energy Performance Incentives (12) Schools at $25M invested with (1) 50-kW Solar PV install per school	0.0111	0.0648	$2,225

Tools: Investment Grade Audits for MT Schools; EPA AVERT Tool

Methodology

IGA Results Summary

School District	Approx. Student Population	Geography	Climate	Total Building Area (ft^2)	Energy Use Intensity (EUI) ($kBtu/ft^2$)	Fuel Type In Addition to Electricity	Total Project Cost	Projected Annual Savings
Anaconda	1000	West	Humid Continental Mild Summer, Wet All Year	247,504	63.7	Natural Gas	$1,364,321	$94,000
Charlo	240	Northwest		55,778	111	Fuel Oil & Propane	$2,413,000	$80,300
Livingston	1300	Central		287,075	60	Natural Gas	$1,925,740	$41,761
Havre	1800	North Central	Cold Semi-Arid Climate	407,517	70.1	Natural Gas	$4,085,680	$23,010
Hinsdale	60	Northeast		46,557	54.3	Natural Gas	$1,303,270	$6,830
St. Regis	200	Northwest	Humid Continental Climate - Dry Cool Summer	22,419	238.1	Propane	$1,159,240	$28,065

IGA Energy Conservation Measure List and Estimated Reduction

School District	HVAC Upgrades	Lighting Upgrades	Weatherization Upgrades	EV Charging	Solar PV	Annual Energy Conserved (MMBtu)	Annual Emissions Reduction (MT CO_2e)
Anaconda	X	X	X			5280	170
Charlo	X	X	X			3661	266
Livingston	X	X	X		X	9219	318
Havre	X		X	X[a]		2409	161
Hinsdale	X					1085	57
St. Regis	X	X				15344	388

Notes:
(a) Havre energy conserved (mmbtu) and emissions reductions do not include utilization of EV charger.

Total Capital Cost and Emissions Reduction for IGA Project Aggregation

Total Project Costs	Annual Emissions Reduction (MT CO_2e)
$12,251,251	1360

(a) Emissions reduction for 2025 - 2030 and 2025 - 2050 accounts the first year of construction and commissioning. Therefore, 4 years of emissions reduction through 2030 and 20-years of reduction through 2050. An average service life of 20-years is applied to the ECMs. Boilers generally have a service life of 15-years but often operate for years afterwards. LED lighting can operate for 20-30 years based on the distribution of total runtime.

CPRG Measure Allocation of Funds

Requested Funds	$24,595,948	
Third Party Implementation	$965,948	
Funds Granted to Schools	$23,630,000	
Cost for Solar PV	$2.80	per watt (based on recent solar projects funded through Montana Energy Bureau at MDEQ)
System Size	50	kW
Number of System Installs	12	count
Total System Size	600	kW
Cost for all Systems	$1,680,000	
Funds Granted to Schools	$23,630,000	
Funds for Solar	$1,680,000	
Funds for Energy Efficiency	$21,950,000	

Match Requirement for Schools

A match will be required for the recipient. 40% of the funding will be allocated to schools in LIDAC communities or that serve LIDAC student populations. These recipients will be required a 5% match for funding. The remaining 60% of funds will be available for any recipient and will require a match up to 25%.

Recipient	CPRG Allocated Funds		Required Match		Total Funds for Retrofits
LIDAC	40%	$9,452,000	5%	$472,600	$9,924,600
Any	60%	$14,178,000	25%	$3,544,500	$17,722,500
				TOTAL	$27,647,100

Retrofits (CPRG + Match)	$27,647,100	
CPRG Funding	$24,595,948	
CPRG Funds % of Total		89%

GHG Emissions Reduction

(12) Projects total at ~$2 Million each including 50 kW Solar PV Array. Calculations assume the following implementation schedule:
Year 1: Program Solicitation, Audits, Design
Year 2: (6) Projects completed
Year 3: (6) Projects completed

Measure	Emissions Reduction - CPRG Funds Only			Emissions Reduction - Total Funds		
	Annual (MT CO_2e)	**By 2030 (MT CO_2e)**	**By 2050 (MT CO_2e)**	**Annual (MT CO_2e)**	**By 2030 (MT CO_2e)**	**By 2050 (MT CO_2e)**
Solar	726	2,524	16,095	726	2,524	16,095
ECMs	2,437	8,530	48,740	3,070	10,743	61,391
TOTAL	**3,163**	**11,053**	**64,836**	**3,795**	**13,267**	**77,486**

Energy Conservation Measures Evaluated from IGAs

All projects generally utilize similar technology for the following ECMs

Lighting Upgrades: Interior and exterior lighting upgrades to LED technology. Either replaced or retrofitted.
Weatherization: Install foam, sealants, and appropriate weather stripping materials to building envelopes.
Vendingmisers: Install occupancy based vending machine controls.
Retro-commissioning: Modify scheduling, setpoints, and operation of HVAC equipment to efficiently provide heating and ventilation to all spaces, while avoiding wasteful energy expenditures.

HVAC upgrade projects differ greatly depending on fuel type and local electricy costs.
Anaconda: Steam boilers will be replaced with new condensing heating hot water (HHW) boilers. Retrofit or replace heating piping and terminal devices for use with HHW. Install a new energy management control system (EMCS) to provide automated direct digital control of the new HVAC systems.

Charlo: Install new Air Source Heat Pump with Electric Resistance heating in rooms.
Hinsdale: Condensing boiler with a dedicated outdoor air system (DOAS) along with a complete replacement of the existing mechanical system since it is currently inefficient and not delivering adequate ventilation to each space.

Energy Conservation and GHG Calculations

Conversions/Factors

3412.14 btu per kWh
0.1 MMBtu per therm

Propane 91500 btu/gal
Fuel oil 138690 btu/gal

Propane 62.88 kg CO2 per MMBtu
Fuel oil 74.14 kg CO2 per MMBtu
Natural gas 52.91 kg CO2 per MMBtu
https://www.eia.gov/environment/emissions/co2_vol_mass.php

Electricity
Used to represent BPA service region
NWPP 634.6 lb CO2/MWh
Reference: eGrid
Used to represent non-BPA service regions of Montana
Montana 0.871 ton CO2/MWh
Reference: AVERT

IGA Baseline and Estimated Savings Summary by Fuel Type

Fuel Type	Baseline					Annual Energy Savings					Annual GHG Savings		
	Peak Annual Demand	Total Annual Demand	Annual Consumption			Total Annual Demand	Annual Consumption						
	kW max	kW total	kWh	therms	gal	kW total	kWh	therms	gal	MMBtu	kg CO_2	lb CO_2	MT CO_2
Anaconda													
Electricty	362	3,528	783,800	--		985	210,550	--	--	--	*Calculated in IGA*		
Natural Gas	--	--	--	157,597		--	--	45,857	--	--			
Subtotal										5,280	--	--	170
Charlo													
Electricty	315	2,627	535,517	--	--	-1,158	-151,556	--	--	-517	--	-96,177	-44
Propane	--	--	--	--	4,167	--	--	--	145	13	834	--	1
Fuel Oil	--	--	--	--	28,986	--	--	--	30,031	4,165	308,793	--	309
Subtotal										3,661	--	--	266

IGA Baseline and Estimated Savings Summary by Fuel Type - Cont.

Fuel Type	Baseline					Annual Energy Savings					Annual GHG Savings		
	Peak Annual Demand	Total Annual Demand	Annual Consumption			Total Annual Demand	Annual Consumption						
	kW max	kW total	kWh	therms	gal	kW total	kWh	therms	gal	MMBtu	kg CO_2	lb CO_2	MT CO_2
Livingston													
Electricty	417	4,036	1,320,532	--	--	126	256,739	--	--	--	*Calculated in IGA*		
Natural Gas	--	--	--	132,409	--	--	--	45,860	--	--			
Subtotal										9,219	--	--	318
Havre													
Electricty	662	6,590	2,146,180	--	--	4	55,609	--	--	190	--	48	44
Natural Gas	--	--	--	212,563	--		--	22,195	--	2,220	117,434	--	117
Subtotal										2,409	--	--	161
Hinsdale													
Electricty	--	--	--	--	--	--	--	--	--	--	--	--	--
Natural Gas	--	--	--	1,966	--	--	--	108	--	1,085	57,396	--	57
Subtotal										1,085	--	--	57
St. Regis													
Electricty	--	--	426,320	--	--	--	135,555	--	--	--	*Calculated in IGA*		
Propane	--	--	--	--	38,830	--	--		10,719	981			
Subtotal										981	--	--	388

Solar PV Systems

The majority utility in Montana provides a net metering opportunity for solar PV systems that are 50-kW or less. Therefore, this analysis considers the measure providing an opportunity to install (12) 50-kW solar PV systems at various Montana school districts.

50-kW System Count	Total kW	Total MW	Annual CO2 Reduction (MT/year)	Emissions Reduction 2025 - 2030[a] (MT CO_2e)	Emissions Reduction 2025 - 2050[a] (MT CO_2e)
12	600	0.6	726	2,524	16,095

Quantified using EPA AVERT Tool

Region: Montana; Distributed (rooftop) solar PV; Power Sector Only

(a) Emissions reductions for 2025 - 2030 and 2025 - 2050 account for 0.5% Solar PV degredation per year.

(b) Implementation schedule considers design and construction in 2025, 50% operation by 2026, and additional 50% operation by 2027

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Attachment 1: Emissions Reduction Calculations Spreadsheet

Measure: School Energy Performance Initiatives
Criteria Pollutant and Hazardous Air Pollutant Emissions Calculations

References
Energy Efficiency and Retrofit Projects: U.S. EPA AP-42 Compilation of Air Emissions Factors from Stationary Sources
Solar PV Projects: AVERT Tool

Summary of GHG Emissions Reductions

Priority Measure	Emissions Reduction by 2030							
	PM_{10}	$PM_{2.5}$	SO_2	NOx	CO	VOC	Pb	HAPs
	tons	tons	tons	tons	tons	tons	tons	lbs
School Energy Performance Incentives (12) Schools at $25M invested with (1) 50-kW Solar PV install per school	0.52	0.48	2.14	5.91	2.85	0.23	9.78E-06	79.7

a) HAPs emissions are only for on-site fuel use. HAPs emissions were not quantified for electrical power generation

Inputs

114,020	therms	Total Natural Gas Conserved
10,864	gal	Total Propane Conserved
30,031	gal	Total Fuel Oil Conserved
658,453	kWh	Total Electricity Conserved, Non-BPA Region
-151,556	kWh	Total Electricity Conserved, BPA Region

Conversions/Factors

3412.14	btu per kWh
0.1	MMBtu per therm
1020	MMBtu per 10^6 scf
1000	kWh to MWh

Propane	91500	btu/gal
Fuel oil	138690	btu/gal

Propane	62.88	kg CO2 per MMBtu
Fuel oil	74.14	kg CO2 per MMBtu
Natural gas	52.91	kg CO2 per MMBtu

https://www.eia.gov/environment/emissions/co2_vol_mass.php

Electricity

Used to represent BPA service region

NWPP 634.6 lb CO2/MWh

reference: eGrid

Used to represent non-BPA service regions of Montana

Montana 0.871 ton/MWh

reference: AVERT

Criteria Pollutant Reductions

Pollutant	Natural Gas[a]		Propane (LPG)[b]		Fuel Oil No.2[c]		Grid Electricity[d]			Total		
	Emission Factor ($lb/10^6$ scf)	Emissions Reduced (lb/yr)	Emission Factor ($lb/10^3$ gal)	Emissions Reduced (lb/yr)	Emission Factor ($lb/10^3$ gal)	Emissions Reduced (lb/yr)	WECC (lb/MWh)	Montana (lb/MWh)	Emissions Reduced (lb/yr)	Emissions Reduced (lb/yr)	Emissions Reduced (ton/yr)	By 2030 (tons)
PM_{10}	7.6	85	0.2	2.2	2	60	--	--	44	191	0.096	0.33
$PM_{2.5}$	7.6	85	0.2	2.2	2	60	0.074	0.074	38	185	0.092	0.32
SO2	0.6	7	0.05	1	0.2	6	0.343	1.114	682	695	0.348	1.22
NOx	100	1118	13	141	20	601	0.553	1.077	625	2485	1.243	4.35
CO	84	939	7.5	81	5	150	0.428	0.428	217	1171	0.585	2.05
VOC	5.5	61	1	11	0.556	17	0.028	0.028	14	103	0.052	0.18
Pb	0.0005	5.59E-03	--	--	9.00E-09	2.70279E-07	--	--	--	5.59E-03	2.79E-06	9.78E-06

a) Emission factors from AP-42 Ch. 1.4 Natural Gas Combustion

NOx and CO emission factors for small boilers (<100 MMBtu/hr)

b) Emission factors from AP-42 Ch. 1.5 Liquefied Petroleum Gas Combustion in Commercial Boilers

c) Emission factors from AP-42 Ch. 1.3 Fuel Oil Combustion

d) Emission factors from eGrid and AVERT. eGrid factors for the WECC Northwest Region only available for PM2.5, NOx, and SO2. WECC NW Region is used to represent electricity generation emissions for BPA-region consumers.

AVERT emission rates represent Central, Northwest, and Rocky Mountain Regions dues to changes in Montana so they are more representative of emissions from power generation servicing the entire state. They are used for non-BPA region consumers and to supplement the WECC column where pollutants were not provided from eGrid.

Neither AVERT or eGrid provides an emission factor for CO, so emissions were factored from VOC emission rates.

Hazardous Air Pollutants

CAS Nbr.	Pollutant	Natural Gas		Propane		Fuel Oil	
		Emission Factor (lb/mmscf)	Emissions Reduced (lb/yr)	Emissions Reduced (lb/yr)	Emissions Reduced (lb/yr)	Emission Factor ($lb/10^3$ Gal)	Emissions Reduced (lb/yr)
7440382	Arsenic	2.00E-04	2.24E-03	4E-09	4.35E-08	4E-09	1.20E-07
71432	Benzene	2.10E-03	0.0235	2.14E-04	2.32E-03	2.14E-04	0.0064
7440417	Beryllium	1.20E-05	1.34E-04	3E-09	3.26E-08	3E-09	9.01E-08
7440439	Cadmium	1.10E-03	0.0123	3E-09	3.26E-08	3E-09	9.01E-08
7440473	Chromium	1.40E-03	0.0156	3E-09	3.26E-08	3E-09	9.01E-08
7440484	Cobalt	8.40E-05	9.39E-04	--	--	--	--
25321226	Dichlorobenzene	1.20E-03	0.0134	--	--	--	--
50000	Formaldehyde	7.50E-02	0.8384	3.30E-02	3.59E-01	3.30E-02	0.99

Hazardous Air Pollutants - Cont.		Natural Gas		Propane		Fuel Oil	
CAS Nbr.	Pollutant	Emission Factor (lb/mmscf)	Emissions Reduced (lb/yr)	Emissions Reduced (lb/yr)	Emissions Reduced (lb/yr)	Emission Factor ($lb/10^3$ Gal)	Emissions Reduced (lb/yr)
110543	Hexane	1.80E+00	20.1213	--	--	--	--
7439965	Manganese	3.80E-04	4.25E-03	6E-09	6.52E-08	6E-09	1.80E-07
7439976	Mercury	2.60E-04	2.91E-03	3E-09	3.26E-08	3E-09	9.01E-08
91203	Naphthalene	6.10E-04	6.82E-03	1.13E-03	1.23E-02	1.13E-03	0.034
7440020	Nickel	2.10E-03	0.0235	3E-09	3.26E-08	3E-09	9.01E-08
7782492	Selenium	2.40E-05	2.68E-04	1.5E-08	1.63E-07	1.5E-08	4.50E-07
108883	Toluene	3.40E-03	3.80E-02	6.20E-03	6.74E-02	6.20E-03	0.19
	o-Xylene			1.09E-04	1.18E-03	1.09E-04	0.0033
Polyaromatic Hydrocarbons (except 7-PAH group)							
91576	2-Methylnaphthalene	2.40E-05	2.68E-04	--	--	--	--
56495	3-Methylcholanthrene	1.80E-06	2.01E-05	--	--	--	--
57977	7,12-Dimethylbenz(a)anthrac	1.60E-05	1.79E-04	--	--	--	--
83329	Acenaphthene	1.80E-06	2.01E-05	2.11E-05	2.29E-04	2.11E-05	0.00063
203968	Acenaphthylene	1.80E-06	2.01E-05	2.53E-07	2.75E-06	2.53E-07	7.60E-06
120127	Anthracene	2.40E-06	2.68E-05	1.22E-06	1.33E-05	1.22E-06	3.66E-05
191242	Benzo(g,h,i)perylene	1.20E-06	1.34E-05	2.26E-06	2.46E-05	2.26E-06	6.79E-05
206440	Fluoranthene	3.00E-06	3.35E-05	4.84E-06	5.26E-05	4.84E-06	0.00015
86737	Fluorene	2.80E-06	3.13E-05	4.47E-06	4.86E-05	4.47E-06	0.00013
85018	Phenanathrene	1.70E-05	1.90E-04	1.05E-05	1.14E-04	1.05E-05	0.00032
129000	Pyrene	5.00E-06	5.59E-05	4.25E-06	4.62E-05	4.25E-06	0.00013
Polycyclic Organic Matter or 7-PAH group Sum of the following:							
56553	Benzo(a)anthracene	1.80E-06	2.01E-05	4.01E-06	4.36E-05	4.01E-06	0.00012
205992	Benzo(b)fluoranthene	1.80E-06	2.01E-05	1.48E-06	1.61E-05	1.48E-06	4.44E-05
205823	Benzo(k)fluoranthene	1.80E-06	2.01E-05	--	--	--	--
53703	Dibenzo(a,h)anthracene	1.20E-06	1.34E-05	1.67E-06	1.81E-05	1.67E-06	5.02E-05
218019	Chrysene	1.80E-06	2.01E-05	2.38E-06	2.59E-05	2.38E-06	7.15E-05
193395	Indenol(1,2,3-cd)pyrene	1.80E-06	2.01E-05	2.14E-06	2.32E-05	2.14E-06	6.43E-05
50328	Benzo(a)pyrene	1.20E-06	1.34E-05	--	--	--	--
		Subtotal	21		0.4		1.2

a) HAPs emissions factors reference the same AP-42 citations as Criteria Pollutants. HAPs emission factors are not published in AP-42 for Propane, so the Fuel Oil factors were used as a surrogate. These likely overestimate HAPs emissions from Propane use.

Pol	Annual Reduction (lb/yr)	Emissions Reduced 2025 - 2030 (lbs)
Total HAPS	22.8	79.7

Solar PV Systems

Offset grid emissions

Pollutant	Annual Emissions Reduced (lb/yr)	Emissions Reduced 2025 - 2030 (lbs)	Emissions Reduced 2025 - 2030 (tons)
PM10	106	371	0.19
PM2.5	90	315	0.16
SO2	530	1855	0.93
NOx	890	3115	1.56
CO	458	1604	0.80
VOC	30	105	0.05

Emissions: AVERT Tool. PM10 emissions are scaled so that PM2.5 represents 85% speciation. CO emissions are scaled from VOC emissions

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Attachment 1: Emissions Reduction Calculations Spreadsheet

Measure: **Strategic Conversion of Fleet Vehicles to Cleaner Alternatives**

References
Argonne National Lab - Alternative fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool
Defaults selected for vehicle mileage and fuel economy.
https://afleet.es.anl.gov/home/

Summary of Emissions Reductions

Priority Measure	Cumulative GHG Emission (MMT CO_2e)		Cost Effectiveness $/MT CO_2e
	By 2030	By 2050	2025 - 2030
Strategic Conversion of Fleet Vehicles to Cleaner Alternatives	0.0035	0.0138	$2,948

Priority Measure	Emissions Reduction by 2030					
	PM_{10}	$PM_{2.5}$	SO_2	NOx	CO	VOC
	tons	tons	tons	tons	tons	tons
Strategic Conversion of Fleet Vehicles to Cleaner Alternatives	1.67	1.27	-0.66	48.10	1.66	3.64

Tools: Argonne National Lab AFLEET Tool; EPA Diesel Emissions Quantifier; EPA AQMD LAX Inventory

Methodology

CPRG Implementation Grant funds will be supplemented with Volkswagen Diesel Settlement funds and match requirements for recipients.
The anticipated total number of vehicles by "vehicle type" to be funded through this measure are determined by vehicle cost, public interest, and available funding.

Local Share	15%	match
	30%	match (AGSE)
VW Share	23%	
CPRG Share	77%	

Budget Breakdown and Vehicle Counts

Vehicle Type	Number	Cost/Vehicle	Total Cost	CPRG Share	VW Share	Local Share
School Bus	11	$400,000	$4,400,000	$2,879,800	$860,200	$660,000
Street Sweeper	3	$640,000	$1,920,000	$1,256,640	$375,360	$288,000
Transit Bus	4	$900,000	$3,600,000	$2,356,200	$703,800	$540,000
Garbage Truck	2	$675,000	$1,350,000	$883,575	$263,925	$202,500
Switcher	1	$2,000,000	$2,000,000	$1,309,000	$391,000	$300,000
AGSE - Push Back	2	$150,000	$300,000	$161,700	$48,300	$90,000
AGSE - Belt Loader	3	$60,000	$180,000	$97,020	$28,980	$54,000
Subtotal	26		**$13,750,000**	$8,943,935	$2,671,565	$2,134,500

Total CPRG Funding	$10,369,695	75%
Total Cost	$13,893,195	100%

GHG Reduction by Vehicle Type

Vehicle Type	Quantity	Vehicle Mileage (mi/year)	Existing Fuel Type	Replacement Type	Existing Fuel Economy (Miles per diesel gallon equivalent, MPDGE)	New Fuel Economy (MPDGE)	Annual GHG per ICE vehicle (short tons CO_2e/quantity)	Annual GHG per replacement (short tons CO_2e/quantity)	Annual GHG Reduction per Quantity (MT CO_2e)	Emissions Reduction 2025 - 2030[a] (MT CO_2e)	Emissions Reduction 2025 - 2050[a] (MT CO_2e)	Estimated Service Life (years)
School Buses	11	15,000	Diesel	EV	7	22.5	443	152	264	1,234	4,966	15
Street Sweeper[b]	3	1,225	Diesel	EV	1.7	6.2	30	9	19	86	226	10
Transit Buses	4	45,000	Diesel	EV	4.4	11.2	563	244	290	1,446	4,703	12
Refuse Truck	2	23,400	Diesel	EV	1.7	6.2	379	115	240	1,095	4,487	15
Switcher Locomotive Engine[c]	1	--	Diesel	Diesel (Tier 4)	--	--	1,215	1,012.5	184	734.8	3,674	20
AGSE - Push Back[d]	2	Note e	Diesel	EV	--	--	22	10.8	10.8	51.7	218	15
AGSE - Belt Loader[d]	3	Note f	Diesel	EV	--	--	27	13.5	13.5	65.0	274	15

(a) Assumes purchase and vehicle delivery occur in Year 1; Full vehicle use occurs over 4 years for 2025 - 2030 period or the lifetime of vehicle for 2025-2050 period
(b) Street sweeper emissions based on refuse truck emissions rates within AFLEET. Vehicle mileage scaled down to account for operational limits compared to refuse trucks (see below)
(c) Switcher locomotive engine emissions based on EPA Diesel Emissions Quantifier (DEQ)
(d) Push back and belt loader emissions are based on equivalent values from the 2020 GSE Emissions Inventory for LAX, EPA AQMD Document
Assume 50% emission reduction for electric airline vehicles
(e) Based on annual fuel consumption per vehicle: 1,054 gal/year (Tier 3 Diesel)
(e) Based on annual fuel consumption per vehicle: 882 gal/year (Tier 2 Diesel)
General Notes
- Electricity carbon intensity based on WECC
- Assesses well-to-wheels petroleum use and GHG emissions along with vehicle operation air pollutants

Criteria Pollutant Reduction by Vehicle Type

Vehicle Type	Quantity	Emissions Reduction per Quantity					
		PM_{10} (lb/yr)	$PM_{2.5}$ (lb/yr)	SO_2 (lb/yr)	NOx (lb/yr)	CO (lb/yr)	VOCs (lb/yr)
School Buses	11	-13.2	-2.9	-125.7	560.3	340.3	70.5
Street Sweeper	3	-0.9	-0.3	-7.0	22.3	13.8	3.3
Transit Buses	4	-32.0	-13.3	-219.7	815.9	583.3	67.7
Refuse Truck	2	-12.0	-3.7	-89.5	283.4	175.5	42.0
Switcher Locomotive Engine	1	1178	872	--	30538	0.0	2254
AGSE - Push Back	2	--	--	--	--	--	--
AGSE - Belt Loader	3	--	--	--	--	--	--

a) Diesel emissions for Switcher Locomotive assume $PM_{2.5}/PM_{10}$ = 74%
b) Criteria pollutant emissions calculations utilize same emissions factor reference as GHG calculations
c) Data unavailable for push back and belt loader

Supporting Calculations

Street Sweeper Vehicle Mileage

Refuse truck (AFLEET default)	23,400	mi/yr
Assumed operation, refuse truck	5	days/week
	52	weeks/year
	260	days/year
	90	miles per day
Street Sweeper Operation	7	miles per day based on TYMCO Sweepers
	5	days/week
	35	weeks/year (excludes winter months)
Street sweeper range	1225	mi/yr

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Measure: **Investment and Improvement in Electric Grid Technology**

References
EPA AVERT Tool
NREL 2018: https://www.nrel.gov/docs/fy18osti/70710.pdf

Summary of GHG Emissions Reductions

Priority Measure	Cumulative GHG Emission ($MMT\ CO_2e$)		Cost Effectiveness $\$/MT\ CO_2e$
	By 2030	By 2050	2025 - 2030
Investment and Improvement in Electric Grid Technology (2) Utility-microgrid projects and (6) critical care facility microgrid projects along with ~2700 ft of distribution line upgrades	0.0243	0.1579	$494

Priority Measure	Emissions Reduction by 2030					
	PM_{10}	$PM_{2.5}$	SO_2	NOx	CO	VOCs
	tons	tons	tons	tons	tons	tons
Grid Upgrades	1.8	1.5	8.9	14.9	0.031	0.48

a) Assumes construction and operation of all facilities is completed within first 2-years of funding period resulting in 3-years of total operation during the 2025-2030 period.
b) Solar PV degredation factor applied over 25-year service life at 0.5% per year.
c) PM10 emissions are scaled so that PM2.5 represents 85% speciation. CO emissions are scaled from VOC emissions

Transmission Upgrades

Cost Estimates - Reconductoring
Represents many upgrade opportunites including advanced inverter functionality, reduce set points, and reconductoring.
Reconductoring is the representative case because it is the generally the most expensive option.
NREL 2018: https://www.nrel.gov/docs/fy18osti/70710.pdf

Distribution

Feeder lines	$187	per foot	(avg, NREL 2018)
Distance Upgraded	2674	ft	
Funding	$500,000		

Micrograds

Cost Estimates - Microgrids

Utility Option

BESS	2	MW	
	2	MWh	
Cost	$4,740,000	(Ravalli Electric Coop Project)	
Utility Solar PV	2	MW	
	$1.32	per W	(Berkley Lab Markets & Policy, 2022)
Land Use	0.13	MW/acre	(Dillon, MT Solar Project)
	15	acres	
Cost	$2,640,000		
Funding	$5,250,000		
No. of Systems	2		

Critical Facility Option

BESS	75	kW
	500	kWh
Solar PV	131	kW, Roof mount
Cost	$1,000,000	(SLO Emergency Center)
General	$3.50	per W (medium rooftop systems)
	$800	per kWh for BESS
Funding	$6,000,000	
No. of Systems	6	

Emissions Estimates

Battery Type	Lithium	
DOD, max	80%	Depth of discharge
Cycle Life	2300	cycles
Lifespan	7	years
	329	cycles/year
Assumes maximum use of battery		
Utility	1051	MWh (annual)
Critical Facility	788571	kWh
	789	MWh (annual)
Total	1840	MWh (annual)

Solar PV, total systems		
Utility	4.0	MW
Critical Facility	786.0	kW
	0.79	MW
Total	4.79	MW

Microgrid	Annual MWh Reduction	Annual GHG Reduction ($MT\ CO_2e/yr$)	Emissions Reduction 2025 - 2030[a] ($MT\ CO_2e$)	Emissions Reduction 2025 - 2050[a] ($MT\ CO_2e$)	Estimated Service Life (years)
Solar (only)	10,990	6,931	0.0205	0.15	25+
Battery (only)	2,000	1,261	0.00378	0.0088	7
Total	12,990	8,192	0.024	0.158	--

a) Assumes construction and operation of all facilities is completed within first 2-years of funding period resulting in 3-years of total operation during the 2025-2030 period.

b) Solar PV degredation factor applied over 25-year service life at 0.5% per year.

Microgrid	Emissions Reduction per Year					
	PM_{10} (lb/yr)	$PM_{2.5}$ (lb/yr)	SO_2 (lb/yr)	NOx (lb/yr)	CO (lb/yr)	VOCs (lb/yr)
Total	1,200	1,020	5,900	9,940	21	320

AVERT Tool. PM10 emissions are scaled so that PM2.5 represents 85% speciation. CO emissions are scaled from VOC emissions

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Projecting Grid Decarbonization 2025 - 2050 and Solar Degradation

Reference:
U.S. EIA Annual Energy Outlook 2023
https://www.nrel.gov/docs/fy12osti/51664.pdf

	IRA Reference Case				Clean Transport - Annual GHG per EV (CO2e/yr)											
Year	Total Electricity Generation (BkWh)	CO_2 (MMst)	CI (MMst CO_2 per BkWH)	CI % of 2025	School Buses		Street Sweeper		Transit Buses		Refuse Truck		AGSE - Push Back		AGSE - Belt Loader	
					short tons	MT	short tons	MT	short tons	MT	short tons	MT	short tons	MT	short tons	MT
2025	507	134	0.265	100%	152	138	9	8	244	221	115	104	11	10	13.5	12.3
2026	508	119	0.233	88%	134	121	8	7	215	195	101	92	9	9	11.9	10.8
2027	508	105	0.207	78%	119	108	7	6	191	173	90	81	8	8	10.6	9.6
2028	538	82	0.153	58%	88	80	5	5	141	128	66	60	6	6	7.8	7.1
2029	559	68	0.121	46%	69	63	4	4	112	101	52	48	5	4	6.2	5.6
2030	570	66	0.117	44%	67	61	4	4	107	97	50	46	5	4	5.9	5.4
2031	573	68	0.118	45%	68	61	4	4	109	99	51	46	5	4	6.0	5.5
2032	577	69	0.120	45%	69	62	4	4	110	100	52	47	5	4	6.1	5.5
2033	579	73	0.126	48%	72	66	4	4	116	106	55	50	5	5	6.4	5.8
2034	581	74	0.127	48%	73	66	4	4	117	106	55	50	5	5	6.5	5.9
2035	580	74	0.128	48%	73	67	4	4	118	107	55	50	5	5	6.5	5.9
2036	583	75	0.128	48%	73	66	4	4	118	107	55	50	5	5	6.5	5.9
2037	585	76	0.130	49%	74	67	4	4	119	108	56	51	5	5	6.6	6.0
2038	580	63	0.109	41%	62	56	4	3	100	91	47	43	4	4	5.5	5.0
2039	587	63	0.108	41%	62	56	4	3	99	90	47	42	4	4	5.5	5.0
2040	597	63	0.106	40%	61	55	4	3	98	89	46	42	4	4	5.4	4.9
2041	603	64	0.107	40%	61	55	4	3	98	89	46	42	4	4	5.4	4.9
2042	608	66	0.108	41%	62	56	4	3	99	90	47	42	4	4	5.5	5.0
2043	611	65	0.107	40%	61	56	4	3	99	89	46	42	4	4	5.5	5.0
2044	615	66	0.108	41%	62	56	4	3	99	90	47	42	4	4	5.5	5.0
2045	620	67	0.109	41%	62	57	4	3	100	91	47	43	4	4	5.6	5.0
2046	621	67	0.107	41%	61	56	4	3	99	90	46	42	4	4	5.5	5.0
2047	629	67	0.106	40%	61	55	4	3	98	89	46	42	4	4	5.4	4.9
2048	635	68	0.107	41%	62	56	4	3	99	90	46	42	4	4	5.5	5.0
2049	639	69	0.108	41%	62	56	4	3	99	90	47	42	4	4	5.5	5.0
2050	642	68	0.106	40%	60	55	4	3	97	88	46	41	4	4	5.4	4.9

Projecting Solar Degradation

Solar	0.50%	avg per year
Wind	0.63%	avg per year

Year	Solar PV Degradation	(12) 50 kW Systems	Utility-Scale 4.79 MW	Wind Degradation	Utility-Scale 100 MW
		MT	MT		MT
2025	100.0%	726	6,931	100.0%	155,628
2026	99.5%	722.1	6,896	99.37%	154,647
2027	99.0%	718.5	6,862	98.74%	153,673
2028	98.5%	714.9	6,827	98.12%	152,705
2029	98.0%	711.2	6,792	97.50%	151,743
2030	97.5%	707.6	6,758	96.89%	150,787
2031	97.0%	704.0	6,723	96.28%	149,837
2032	96.5%	700.3	6,688	95.67%	148,893
2033	96.0%	696.7	6,654	95.07%	147,955
2034	95.5%	693.1	6,619	94.47%	147,023
2035	95.0%	689.5	6,584	93.88%	146,096
2036	94.5%	685.8	6,550	93.28%	145,176
2037	94.0%	682.2	6,515	92.70%	144,261
2038	93.5%	678.6	6,480	92.11%	143,353
2039	93.0%	674.9	6,446	91.53%	142,449
2040	92.5%	671.3	6,411	90.96%	141,552
2041	92.0%	667.7	6,376	90.38%	140,660
2042	91.5%	664.1	6,342	89.81%	139,774
2043	91.0%	660.4	6,307	89.25%	138,893
2044	90.5%	656.8	6,272	88.69%	138,018
2045	90.0%	653.2	6,238	88.13%	137,149
2046	89.5%	649.5	6,203	87.57%	136,285
2047	89.0%	645.9	6,168	87.02%	135,426
2048	88.5%	642.3	6,134	86.47%	134,573
2049	88.0%	638.7	6,099	85.93%	133,725
2050	87.5%	635.0	6,065	85.39%	132,883