C-1-A. Use Electric or Hybrid Powered Equipment

Photo Credit: Granite Construction, March 2019

GHG Mitigation Potential

Potentially large reduction in GHG emissions from construction equipment

Co-Benefits (icon key on pg. 34)

Climate Resilience

Using electric- or hybrid-powered equipment can reduce sensitivity to fuel price shocks or scarcity. However, using all-electric equipment may decrease resilience if they are the only option available during a power outage.

Health and Equity Considerations

This measure will not only reduce air pollution for surrounding communities but also for onsite workers.

Measure Description

This measure requires use of electric- or hybrid-powered construction equipment over conventional diesel-fueled counterparts. Replacing diesel-powered equipment with electric or hybrid-electric equipment reduces fossil fuel combustion and thus GHG emissions. However, all-electric equipment results in GHG emissions from the electricity used to charge the equipment. The indirect GHG emissions increase from electricity must be calculated in addition to the GHG emissions reduction from displaced fossil fuel combustion to estimate the total net GHG emissions reduction achieved by this measure if using all-electric equipment. A variation of this measure is described in Measure C-1-B, *Use Cleaner-Fuel Equipment*.

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

Note that while this measure discusses offroad equipment used for construction, this measure can also be implemented for other offroad equipment applications (e.g., agriculture, industrial).

Cost Considerations

Electric- or hybrid-powered equipment tends to be more expensive to purchase and install than conventional models powered by fossil fuels. These costs may be offset by savings in fuel use and maintenance.

Expanded Mitigation Options

Pair with Measure E-10, *Procure Electricity from Lower Carbon Intensity Power Supply*, to ensure that the energy supplied to power the electrified equipment has a lower carbon intensity than the local grid, thereby further reducing GHG emissions. Consider using portable batteries to support and extend implementation of this measure at more remote sites.

GHG Reduction Formula

$$A1 = (C \times D \times F \times G1 \times H) - (C \times D \times \mathbf{G2} \times I)$$

$$A2 = C \times D \times E \times \mathbf{G2} \times I$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A1	GHG reduction from using electric equipment	[ ]	MT CO_2e	calculated
A2	GHG reduction from using hybrid equipment	[ ]	MT CO_2e	calculated
User Inputs				
B	Fuel type of existing equipment	[ ]	text	user input
C	Hours of equipment operation	[ ]	hours	user input
G2	Carbon intensity of fossil-fueled equipment	[ ]	g CO_2e per hp-hour	CARB 2021
Constants, Assumptions, and Available Defaults				
D	Horsepower of equipment	Table C-1-B.1	hp	CARB 2021
E	Percent fuel reduction of hybrid equipment compared to conventional equipment	10	%	Holian and Pyeon 2017
F	Conversion from horsepower to MW	0.0007457	MW per hp	conversion
G1	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021
H	Conversion from lb to MT	0.000454	MT per lb	conversion
I	Conversion from g to MT	1 e^{-6}	MT per g	conversion

Further explanation of key variables:

- (B) – The fuel type of the existing equipment is used to obtain the carbon intensity of the equipment (G2) from OFFROAD.
- (D) – Average hp of various construction equipment are provided in Table C-1-B.1 in Appendix C, *Emission Factors and Data Tables* (CARB 2021). If the user can provide an equipment-specific hp, they should replace the default in the GHG calculation formula.
- (E) – The percent fuel reduction is used in this formula as a proxy for the percent activity reduction that would be expected with hybrid construction equipment. Based on a survey of 12 models of heavy construction equipment from 10 different manufacturers, hybrid construction equipment reduced fuel use by 10 to 45 percent, with an average of 28 percent (Holian and Pyeon 2017). To be conservative, the low end of the range is cited. If the user can provide an equipment-specific hp, the user should replace the default in the GHG calculation formula. If the user knows the make and model of the construction equipment used, the user should replace the default in the GHG calculation formula.

- (F) – Conversion factor assumes that energy requirements and losses are the same for both a fuel-powered engine and an electrically-charged engine.
- (G1) – GHG intensity factors for major California utilities are provided in Tables E-4.3 and E-4.4 in Appendix C. If the project study area is not serviced by a listed electricity provider, or the user is able to provide a project-specific value (i.e., for the future year not referenced in Appendix C), the user should replace the default in the GHG calculation formula. If the electricity provider is not known, the user may elect to use the statewide grid average carbon intensity.
- (G2) – GHG intensity factors for various construction equipment can be obtained from CARB's (2021) OFFROAD model. Note that the OFFROAD emissions rates are inclusive of equipment load. Therefore, the GHG reduction equation does not include a multiplier for load factor.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user reduces construction equipment emissions by replacing fossil fuel combustion with electricity consumption, which generates fewer GHG emissions per unit of activity. In this example, a 158-hp diesel excavator (D) that is used 8 hours per day (C) is replaced by an electric-powered equivalent. A 158-hp excavator has a carbon intensity of 530 g CO_2e per hp-hour (G2). The electricity provider for the project area is Silicon Valley Clean Energy, and the analysis year is 2025. The carbon intensity of electricity is, therefore, 5 lb CO_2e per megawatt-hour (G1).

$$A1 = \left(8\ \frac{\text{hours}}{\text{day}} \times 158\ \text{hp} \times 0.0007457\ \frac{\text{MW}}{\text{hp}} \times 5\ \frac{\text{lb CO}_2\text{e}}{\text{MWh}} \times 0.000454 \frac{\text{MT}}{\text{lb}}\right) - \left(8\ \frac{\text{hours}}{\text{day}} \times 158\ \text{hp} \times 530\ \frac{\text{g CO}_2\text{e}}{\text{hp-hour}} \times 1e^{-6} \frac{\text{MT}}{\text{g}}\right) = -0.7 \frac{\text{MT CO}_2\text{e}}{\text{day}}$$

Quantified Co-Benefits

Improved Air Quality

Reducing fossil-fuel combustion will also reduce local criteria pollutants. Emission savings can be calculated using the same formula used to quantify GHG reductions (A1 and A2). Criteria pollutant intensity factors for various construction equipment can be obtained from CARB's (2021) OFFROAD model.

Electricity supplied by statewide fossil-fueled or bioenergy power plants will generate criteria pollutants. However, because these power plants are located throughout the state, electricity consumption from equipment charging will not generate localized criteria pollutant emissions at the equipment source. Consequently, for the quantification of criteria pollutant emission reductions, either

the electricity portion of the equation can be removed, or the electricity intensity (G2) can be set to zero.

Energy and Fuel Savings

Fossil fuel savings are a product of the equipment fuel efficiency (gallons consumed per hour) and the equipment operating time (hours). Fuel intensity factors for various construction equipment can be obtained from CARB's OFFROAD model. Users should multiply the fuel intensity by the equipment operating hours to quantify fuel savings.

Increased electricity consumption for electric equipment is calculated as part of the GHG reduction formula (A1). The abbreviated formula is also shown below.

$$MWh = C \times D \times F$$

Sources

- California Air Resources Board (CARB). 2021. OFFROAD2017–ORION. Available: https://arb.ca.gov/emfac/emissions-inventory. Database queried by Ramboll and provided electronically to ICF. September 2021.
- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.
- Holian, M., and J. Pyeon. 2017. *Analyzing the Potential of Hybrid and Electric Off-Road Equipment in Reducing Carbon Emissions from Construction Industries*. Mineta Transportation Institute. September. Available: https://transweb.sjsu.edu/sites/default/files/1533-analyzing-the-potential-of-hybrid-and-electric-off-road-equipment-in-reducing-carbon-emissions-from-construction-industries-research-brief.pdf. Accessed: January 2021.