N-8. Agricultural Equipment Efficiency

GHG Mitigation Potential

Large

Potentially large reduction in GHG emissions from agricultural equipment

Co-Benefits (icon key on pg. 34)

Climate Resilience

Improving agricultural equipment efficiency through use of electric- or hybrid-powered equipment can reduce sensitivity to fuel price shocks or scarcity in conventional fuels. However, using all-electric equipment may decrease resilience if it is the only option available during a power outage.

Health and Equity Considerations

Replacing diesel and gas-powered equipment with cleaner-fuel or electric equipment reduces the risk of pollutant-related health conditions and effects related to noise pollution for the user and surrounding communities.

Measure Description

This measure requires use of electric- or hybrid-powered, off-road agricultural equipment over conventional diesel-fueled counterparts during agricultural activities. Replacing diesel-powered, off-road agricultural 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-powered equipment. Variations of this measure are described in Measure C-1-A, *Use Electric or Hybrid Powered Equipment*, Measure M-6, *Off-Road Equipment Efficiency*, and Measure C-1-B, *Use Cleaner-Fuel Equipment*.

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

Note that while this measure discusses off-road equipment used for agricultural purposes, this measure can also be implemented for other off-road equipment applications (e.g., construction, general purposes).

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

$A1=(C\times D\times F\times G1\times H)-(C\times D\times \mathbf{G2_B}\times I)$

$A2=(C\times D\times E\times \mathbf{G2_B}\times I)$

GHG Calculation Variables

ID	Parameter	Value	Unit	Source
Output				
A1	GHG reduction from using electric off-road agricultural equipment	[ ]	MT CO_2e	calculated
A2	GHG reduction from using hybrid off-road agricultural 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 fuel off-road equipment	[ ]	g CO_2e per hp-hour	CARB 2021; CAPCOA 2023
Constants, Assumptions, and Available Defaults				
D	Horsepower of electric or hybrid off-road equipment	[ ]	hp	user input; CARB 2023; CA CORE 2023
E	Percent fuel reduction of hybrid equipment compared to fossil fuel equipment	10	%	Holian and Pyeon 2017
F	Conversion from horsepower to MW	0.0007457	MW per hp	conversion
G1	Carbon intensity of local utility provider	Tables E-4.3 and E-4.4	lbs CO_2e per MWh	CA Utilities 2021
H	Conversion from lbs to MT	0.000454	MT per lb	conversion
I	Conversion from grams to MT	1 e^{-6}	MT per gram	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.
- (C) – This input represents the hours of operation that the equipment will be used over a user-specified time period.
- (D) – The horsepower of the electric agricultural equipment that is electric will need to be provided by the user.
- (E) – The percent fuel reduction is used in this formula as a proxy for the percent activity reduction that would be expected with hybrid, off-road, heavy-duty equipment. Based

on a survey of 12 models of off-road, heavy-duty equipment from 10 different manufacturers, hybrid off-road 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 agricultural equipment, 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 T-13.1 and T-13.2 in Appendix C. If the project study area is not serviced by a listed utility, 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 utility is not known, the user may elect to use the statewide grid average carbon intensity.
- (G2) – GHG intensity factors for various off-road 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. In addition, GHG intensity factors for various off-road equipment can be obtained from the User Guide for CalEEMod: Appendix G.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user reduces agricultural equipment emissions by replacing fossil-fuel combustion with electricity consumption, which generates fewer GHG emissions per unit of activity. In this example, an agricultural farm is replacing a 2020 model year 70-hp diesel tractor (D) that is used 8 hours per day (C) with an electric-powered equivalent (CARB 2023; CA CORE 2023). A 2020 model year 70-hp diesel tractor has an approximate carbon intensity of 530 grams CO_2e per hp-hour (G2). The electric utility for the project area is Pacific Gas & Electric Company, and the analysis year is 2025. The carbon intensity of electricity is, therefore, 206 lbs CO_2e per megawatt-hour (G1).

$$A=\left(8\ \frac{\text{hours}}{\text{day}}\times 70\ \text{hp}\times 0.0007457\ \frac{\text{MW}}{\text{hp}}\times 206\ \frac{\text{lbs}\ CO_2e}{\text{MWh}}\times 0.000454\frac{\text{MT}}{\text{lb}}\right)-\left(8\ \frac{\text{hours}}{\text{day}}\times 70\ \text{hp}\times \mathbf{530}\ \frac{\text{g}\ CO_2e}{\text{hp-hour}}\times 1\text{x}10^{-6}\frac{\text{MT}}{\text{g}}\right)=-0.26\ \frac{\text{MT}\ CO_2e}{\text{day}}$$

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 off-road equipment can be obtained from CARB's (2021) OFFROAD model.

Electricity supplied by statewide fossil-fueled 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 (G1) 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 off-road equipment can be obtained from CARB's (2021) 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 (A). The abbreviated formula is also shown below.

$$\text{MWh} = C \times D \times F$$

Sources

- California Air Pollution Control Officer's Association (CAPCOA). 2023. User Guide for CalEEMod Version 2022.1: Appendix G, Default Data Tables Available: https://caleemod.com/user-guide. Accessed: January 2024.
- California Air Resources Board (CARB). 2021. OFFROAD2021–ORION. Available: https://arb.ca.gov/emfac/emissions-inventory. Accessed: December 2023.
- California Air Resources Board (CARB). 2023. CARB Advanced Clean Off-road Equipment List Fact Sheet. August. Available: https://ww2.arb.ca.gov/sites/default/files/classic/ZEE/2023%20ZEE%20List%2008182023%20CORE%20TRL%20No%20Hybrid.pdf. Accessed: December 2023.
- 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.
- Clean Off-Road Equipment Voucher Incentive Project (CA CORE). 2023. Eligible Equipment Catalog. Available: https://californiacore.org/equipmentcatalog/. Accessed: December 2023.
- 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/research/Analyzing-Potential-Hybrid-and-Electric-Road-Equipment-Reducing-Carbon-Emissions-Construction-Industries. Accessed: December 2023.