AEM
Association of Equipment Manufacturers

OFF-ROAD GREENHOUSE GAS PROTOCOL FOR SCOPE 3 CATEGORY 11

BACKGROUND

The Greenhouse Gas Protocol Initiative, a multi-stakeholder partnership, establishes a standardized framework to measure and manage greenhouse gas (GHG) emissions from private and public sector operations, products, and value chains. The Association of Equipment Manufacturers (AEM) has reviewed the Greenhouse Gas Protocol and has drafted additional guidance, specifically addressing use phase greenhouse gas emissions pertaining to heavy-duty off-road equipment. AEM is the North American-based international trade group of equipment manufacturers and suppliers with more than 1,000 member companies and over 200 product lines in the construction, agriculture, mining, forestry, and utility industries. The goal is to create uniformity and harmonization among those companies attempting to monitor, track, and report use- phase GHG emissions.

ABSTRACT

This document focuses specifically on Scope 3 Category 11 emissions from use of sold off-road equipment, including large-scale fixed installations combined of several types of apparatus. This is a starting point for manufacturers of heavy-duty off-road equipment. Category 11 includes emissions from the use of equipment sold by the reporting company in the reporting year. A reporting company's scope 3 emissions from use of sold products comprise a portion of the scope 1 and scope 2 emissions of end users. End users include both consumers and business customers that use final products. The goal is to use the tools provided by the GHG Protocol to draft a useful guide for equipment manufacturers.

AEM SUSTAINABILITY COUNCIL

The Sustainability Council is focused on moving the industry forward faster by aligning the industry as it prepares for increasing stakeholder expectations, existing, and developing ESG (Environmental, Social, and Governance) regulations to reduce member risk.

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Introduction

Manufacturers of heavy-duty off-road equipment face challenges calculating and reporting the energy-related environmental impacts of their products when in use, specifically, scope 3 category 11 greenhouse gas emissions (GHG) in products with multiple energy sources and which are designed for longer lifetime use. Reflecting a deeply held conviction in sustainability, the Association of Equipment Manufacturers (AEM)[1] is providing practical guidance for industry alignment of scope 3 category 11 GHG reporting. Consistency in measuring energy consumption and product lifetime will support industry alignment. AEM aims to provide industry consensus for member companies to rely upon and to create industry guidance for off-road heavy-duty machinery.

This industry guidance for greenhouse gas monitoring is a tool for companies to use on their journey toward reporting scope 3 category 11 metrics. In this guidance document AEM has built on works accomplished by the World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD) in the original Greenhouse Gas Protocol[2]. Our goal is to implement the following guidance by encouraging member companies to have:

- Robust policies and procedures across the company and business relationships
- Enhanced third party/client due diligence across the company and supply chain
- Stakeholder engagement
- Third-party auditors/verification
- Public reporting

GHG Emissions

Measurements of GHG emissions are aimed to consistently compare the impact of each greenhouse gas to the quantity of carbon dioxide equivalent required to produce the same degree of warmth. Different greenhouse gases can trap heat in the atmosphere at different rates and atmospheric lifetimes, expressed through global warming potentials (GWP). Meaningful comparisons between gases rely on carbon dioxide equivalent as a benchmark for measuring the heat-trapping ability of greenhouse gases. Carbon dioxide equivalent (or CO_2e) is stated as a single number in this manner. GHG accounting totals are expressed in CO_2e.

According to the GHG Protocol Initiative, “Companies shall account for scope 3 emissions of CO_2e, CH_4, N_2O, HFCs, PFCs, and SF_6, if they are emitted in the value chain.” All-natural sources of GHG emissions (for example, biogenic emissions) are excluded from the calculation in this guidance; however, these emissions should still be reported separately.

Focus: Scope 3 Category 11 – Use of Sold Products

As defined by the GHG Protocol, GHG emissions from the use of sold products (scope 3 category 11) include goods and services sold by the reporting company in the reporting year.[3] These emissions can potentially create operational and monitoring risks for the original equipment manufacturer or reporting company. A reporting company’s scope 3 GHG emissions, from use of sold products, represent emissions that will be an end user’s scope 1 and 2 emissions over the product’s lifetime. End users include both consumers and business partners that use the reporting company’s manufactured products. These emissions are broken into two types: direct use phase emissions and indirect use phase emissions. AEM will focus on direct use phase emissions as they are most relevant to member companies who manufacture heavy-duty off-road equipment.

Types of Emissions	*Product Type*	*Examples*
Direct use-phase emissions *(Required)*	Products that directly consume energy (fuels or electricity) during use	Automobiles, aircraft, engines, motors, power plants, buildings, appliances, electronics, lighting, data centers, web-based software
	Fuels and feedstocks	Petroleum products, natural gas, coal, biofuels, crude oil
	Greenhouse gases and products that contain or form greenhouse gases that are emitted during use	CO2 , CH4 , N2 O, HFCs, PFCs, SF6 , refrigeration and air-conditioning equipment, industrial gases, fire extinguishers, fertilizers
Indirect use-phase emissions *(Optional)*	Products that indirectly consume energy (fuels or electricity) during use	Apparel (requires washing and drying), food (requires cooking and refrigeration), pots and pans (require heating), soaps and detergents (require heated water)

Figure 1: Emissions from Use of Sold Products. Source: Table 5.8 from the Scope 3 Standard

Key Considerations

Product Definitions

Due to the diversity of product types and customer applications, examples of products that directly consume energy in our sector include, but are not limited to:

A. Non-Road Mobile Machines, heavy-duty off-road equipment that meets any of the following criteria:

   a. Equipment that is self-propelled or serves a dual purpose by both propelling itself and performing another function. Examples are garden tractors, off-highway mobile cranes, bulldozers.
   b. Equipment intended to be propelled by another device while performing its function. Examples are agricultural mowers, scrapers.
   c. Equipment, either portable or transportable, designed to be and capable of being carried or moved from one location to another. Examples are mobile generators and light towers.

B. Large-Scale Fixed Installations combining several types of apparatus and, where applicable, other devices intended to be used permanently in a predefined and dedicated location. Examples are tower cranes, stationary engines, generators, turbines.

Boundaries

The GHG Protocol defines methods for setting boundaries for a greenhouse gas inventory in its *Corporate Value Chain (Scope 3) Accounting and Reporting Standard*. For non-road mobile machinery, setting organizational boundaries can look a little different because of complex organizational structures and complexity of product use cases. The GHG Protocol guidance establishes minimum boundaries of each scope 3 category 11 in order to standardize the boundaries and help companies understand which activities should be accounted for.[4]

Complex organizational structures can lead to increased estimations of emissions metrics. Compliance and sustainability departments are challenged when gathering data from other business areas. In the off-road industry, these varying business areas may be spread across different sectors (agriculture, construction, mining, forestry, or utility), making it challenging to gather emissions data and/or get all business areas to agree on how to present the data. Currently, no standard guidance for reporting exists, and organizations aren't consistently measuring the same factors as their peers. The more that's done to ensure industry peers get aligned with one another sooner than later, the better off equipment manufacturing – and our environment – will be in the long term.

End-of-life treatment for heavy-duty off-road machinery can also vary from other industries. For example, automobiles can end their lives due to total loss after an accident, economic write-off, non-compliance with new safety or emissions standards, or a change in design preferences. According to an EPA report[5] on processing end-of-life machines, "Every year, machines that reach the end of their useful life end up as discarded machines. Often these machines are abandoned or stockpiled at poorly managed scrap yards." However, non-road machinery has very different end-of-life results. Remanufacture, overhaul, and recycling are all practiced by many original equipment manufacturers, along different product lines. These practices can significantly increase useful life and set manufacturers of non-road machinery apart from others.

Moreover, the way products are sold varies from other industries. Those who manage and maintain heavy, off-road fleets may lease or rent equipment for specific job sites. Products can be sold or rented directly from the original equipment manufacturer or through a dealer, based on each company's business model.

The key here is consistently applying the same approach when defining entities and assets. The table below shows the U.S. EPA outline for consolidation approaches for setting organizational boundaries, originally cited in the GHG Protocol.

Consolidation Approach	Description
Equity share	An organization accounts for GHG emissions from operations and assets according to its share of equity in the operation. The equity share reflects economic interest, which is the extent of rights an organization has to the risks and rewards flowing from an operation.
Financial control	An organization accounts for 100% of the GHG emissions over which it has financial control. It does not account for GHG emissions from operations it owns equity in but does not have financial control over. The organization has financial control over the operation if it can direct the operation's financial and operating policies with a view to gaining economic benefits from the operation's activities. The organization may have financial control over the operation even if it has less than 50% equity in that operation.
Operational control	An organization accounts for 100% of the GHG emissions over which it has operational control. It does not account for GHG emissions from operations it owns equity in but does not have operational control over. An organization accounts for 100% of emissions from operations over which it or one of its subsidiaries has operational control. If the organization is the operator of a facility, it will have the full authority to introduce and implement its operating policies and thus has operational control.

Figure 2: consolidation approaches for setting organizational boundaries, originally cited in the GHG Protocol

Beneficial Ownership Rules

A *wholly owned subsidiary* is a company whose common stock is 100% owned by another company. When a company owns less than 50% of another company, it holds a *minority interest* in that company. For example, firm ABC owns 25% of XYZ company, 70% of DEF company, and 100% of GHI company. XYZ is a minority interest, DEF is a subsidiary, and GHI is a wholly owned subsidiary. A subsidiary is a separate distinct legal entity for tax, regulation, and liability purposes. Corporations also use subsidiaries to manufacture or market different brands owned by the parent company.

Recommendation: AEM recommends applying a beneficial ownership rule to GHG emissions which reflects equity share: where emissions are reported if a firm holds *51% (or more) controlling interest* in a company or *full operational control* in a company. This will eliminate double-counting risks and create accountability for beneficial ownership purposes.

How to Calculate and What Data Do I Need to Quantify?

Knowledge of CO_2e (carbon dioxide equivalent) is useful for measuring carbon footprints. The aim is to consistently compare the impact of each greenhouse gas to the quantity of CO_2e required to produce the same degree of warmth. A carbon footprint, which comprises numerous greenhouse gases, can be stated as a single number in this manner.

Note: The European Commission measures in carbon dioxide equivalent, notated as "CO_2e." These units of measurement can differ from units in other countries. For example, this document will cite United

States Environmental Protection Agency (EPA) inventories, which may look different from those of the EU, considering differences in units of measurement.

According to the EPA[6], the GHG inventory development process consists of four key steps:

1. Review accounting standards and methods, determine organizational and operational boundaries, and choose a base year
2. Collect data and quantify GHG emissions
3. Develop a GHG inventory management plan to formalize data collection procedures
4. Set a GHG emission reduction target; track and report progress

AEM member companies should methodically and intentionally implement a GHG emissions program that includes these steps in the process.

Consumption Data Segmentation Considerations

If a company sells a large selection of products, or if the use phase of multiple products is similar, it may be useful to group similar products and use statistical averages for a typical product in the product group. Accuracy of longer-term average data for hours used for machine emissions is like a disassembled puzzle. Incorporating the different variables is like starting to assemble that puzzle and will tell a more accurate story of how customer uses can impact emissions calculated. Energy consumption and customer application can change and consequently alter emissions data.

For example, if Company A has a customer, Nick, who is a grower and bought the tractor Company A produces, which could be used for planting, tilling, spraying, and side dressing, then both Company A and Nick know he will need varying levels of horsepower for each operation. Tillage work will require more horsepower than planting and will result in higher energy consumption. The accuracy of Company A's emissions data is now greater because it incorporated data points based on customer application and consistent energy consumption. If Nick uses his tractor for planting, tilling, side dressing, and spraying over the long term, then unit level emissions data will vary. Over an extended period, the manufacturer could use this data overlayed with number of units sold annually to discern use of sold product emissions as indicated by the following equation:

CO_2e emissions from use of sold products **=**

sum of CO_2e across fuels consumed from use of products:

Σ (total lifetime expected uses of product **×** number sold in reporting period **×** fuel consumed per use × emission factor for fuel)

+

sum of CO_2e across electricity consumed from use of products:

Σ (total lifetime expected uses of product **×** number sold in reporting period **×** electricity consumed per use **×** emission factor for electricity)

Figure 3: CO_2e equivalent emissions from use of sold products[7]

Companies should reference EPA's Emission Factors for Greenhouse Gas Inventories for categorizations of annual sales volume, available at https://www.epa.gov/climateleadership/ghg-emission-factors-hub.

Calculating GHG emissions from category 11 typically requires product design specifications and assumptions on how consumers use products (user profiles, assumed product lifetimes). However, for heavy-duty off-road equipment, specifications are unique. Heavy-duty off-road equipment is primarily used off-road but can be occasionally driven/used on-road. It is useful to ensure these distinctions are understood as we craft the methodology for calculating scope 3 category 11 emissions.

Calculating Direct Use Phase Emissions from the Use of Energy in Products

Manufacturers of heavy-duty off-road equipment may encounter challenges in tracking a product to end-of-life and then reporting those emissions accurately, given some products can have decades-long life cycles depending on hours used. For products that emit GHGs, use phase emissions are calculated by multiplying the quantity of products sold by the GHGs released during the product lifetime and then by the global warming potential (GWP) of the greenhouse gases released.

To reduce the potential for emissions data to be misinterpreted or double-counted, AEM recommends that companies should also track and monitor relevant information such as product life cycles and emissions intensity metrics. Relevant emissions intensity metrics may include annual emissions per product, energy efficiency per product, emissions per hour of use, emissions per load capacity, emissions per functional unit, etc.

Data collected for these calculations should include:

1. Annual number of units sold
2. Quantities of GHGs emitted per product
3. GWP of the GHGs emitted in the product, expressed in units of CO2e per unit kilogram of the GHG

CO_2e emissions from greenhouse gases and products that emitted or from greenhouse gases that are emitted during use **=**

sum across GHGs released in a product or product group:

Σ (GHG emitted per product **×** total number of products sold

× % of GHG released during lifetime use of product **×** GWP of the GHG)

then:

sum across products or product groups:

Σ (use phase emissions from product or product group 1,2,3…)

Note: if the % released is unknown 100% should be assumed.

Figure 4: Direct use phase emissions from greenhouse gases and products that contain or emit GHGs

Hydrofluorocarbon Leakage

Hydrofluorocarbons (HFCs) are man-made organic compounds that contain fluorine and hydrogen atoms and are most commonly found in air conditioners and refrigeration equipment. Most are gases at room temperature and pressure. Companies should assess the impact of HFCs based on their product portfolio and determine if relevant. For non-road mobile machines and large-scale fixed installations, emissions from HFCs may be immaterial compared to emissions from energy consumed by those same products.

According to the Washington State Department of Ecology, equipment containing 50 pounds or more of refrigerant is estimated to leak the equivalent of 5.8 million metric tons of CO_2 equivalent (MMTCO2e) statewide every year. Of this leakage, they estimate 3.4 MMTCO2e are HFCs. For comparison, a household refrigerator typically contains 0.5 pounds of refrigerant, while a building chiller may contain over 1,000 pounds.

The GHG Protocol recommends measuring kg HFC emitted per kg of product sold. Please see the U.S. EPA Emission Factors for Greenhouse Gas Inventories[8] for the global warming potential (GWP) multiplier, to solve for the CO_2e.

Deriving Required Data

Annual Number of Units Sold

Unit sales volumes are reported at a level of granularity determined by each company to realistically get an accurate understanding of product GHG emissions. AEM recommends using revenue recognition as a generally accepted accounting principle for measuring number of units sold. In this calculation, revenues are recognized on the income statement in the period when realized and earned, yet not necessarily when cash is received. Realizable means that goods or services have been received by the customer, but payment for the good or service is expected later.

Unit sales appear on a company's income statement and are examined over different accounting periods, such as monthly, quarterly, or yearly. As applied to heavy-duty off-road equipment, this process is contingent on the industry definition of annual sales volume. As a function of accounting, volumes that define sales revenue can be collected from the income statement and categorized among the different sources (for example, stationary combustion, mobile combustion, refrigerants, electrical grid, among others) and type of energy consumed (natural gas, diesel, electricity, among others).

Product Life of Units Sold

Tracking scope 3 category 11 emissions can show GHG reductions from efficiency improvements and can also show increases from durability improvements. Because the scope 3 inventory accounts for total product-life (also referred to as design-life) GHG use phase emissions, companies that produce more durable products with longer life cycles will have larger emissions profiles. As product life cycles increase, scope 3 use phase emissions increase, assuming all else is constant.

Recommendation: AEM recommends product life should incorporate the complete expected lifetime of the product, including any remanufacture/rebuilds expected over the lifetime. Please keep in mind the risk of double counting. Ideally, remanufactured heavy-duty off-road equipment should match the same customer expectation as new machines; therefore, data taken from original manufacture should also cover any remanufacture activities.

Remanufacture and Overhaul Equipment

Life cycle assessment (LCA) and greenhouse gas inventories are two key measurement tools being used to track an organization's environmental impact, but what happens when remanufacturing extends the product's life cycle and inventories? Put simply, remanufacturing is an industrial process turning used products into a condition of like new or better. According to Rochester Institute of Technology's (RIT's) Golisano Institute for Sustainability[9], we can compare an original manufacturing cycle to a remanufacturing cycle to better understand the related environmental impacts.

An unintended consequence of remanufacturing is that the original product life GHG emissions are extended because of remanufacturing. Consideration of product life is open to interpretation. AEM recommends considering the life of the product as described in RIT's *Manufacturing vs. Remanufacturing* summary.

Steps to remanufacture a product are very different to the original manufacture and can alter the product to a high degree.

Original Manufacture	Remanufacture
1. Extraction: Raw materials	1. Core acquisition: The failed component from Step 7 in the first column is acquired by a remanufacturer
2. Refinement: Extracted raw materials are transported and refined for industrial use	2. Disassembly
3. Processing and part manufacturing	3. Condition assessment: Each piece of the dismantled component is inspected to determine its condition

4. Assembly: All the different parts of the component are sent to an assembly plant where the component is built	4. Cleaning: Usable and repairable parts then undergo an intensive cleaning process
5. Distribution and sale: The new heavy-duty off-road equipment is distributed and sold, beginning a service life that lasts 60 years of use on average	5. Repair: Repairs and any necessary improvements to the parts are made using a wide range of processes
6. Service life: The component is maintained over the course of the machine's life	6. Assembly: An entirely new component is built (reassembled) using the refurbished parts
7. End of life: Eventually, the heavy-duty off-road equipment as a whole or the component reaches the end of its service life	7. Testing: The performance of the remanufactured component is tested
	8. Service life: The component is delivered and begins its new service life
	9. Core return: The component reaches the end of its useful life and can be sent back into the remanufacturing process

Figure 5: RIT's Manufacturing vs. remanufacturing summary

Energy Consumption

Energy consumption per use of sold products is activity data used in calculations outlined in this guidance document.

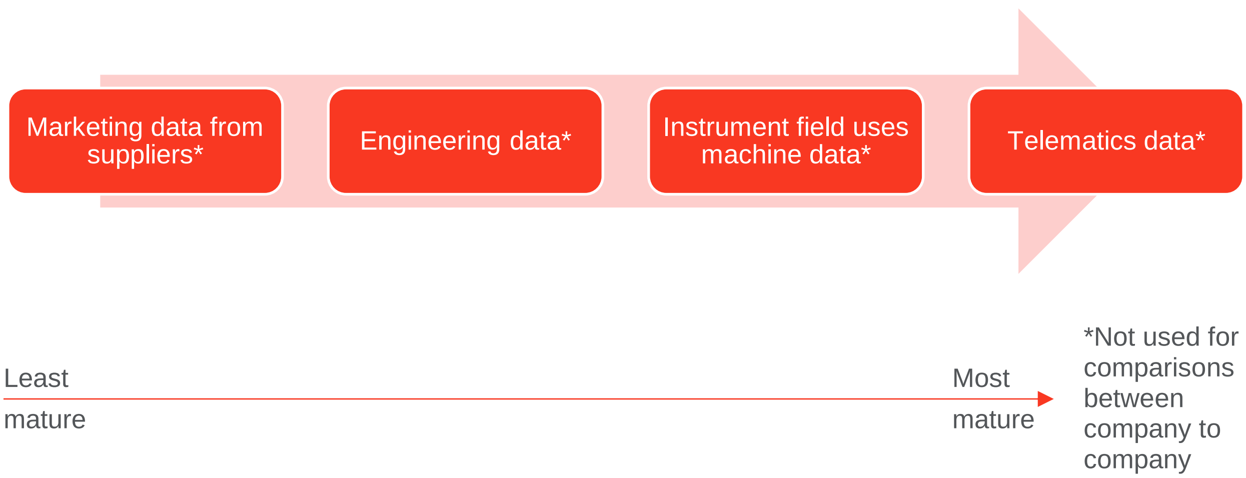

Figure 6: Types of activity data used in energy calculations.

Data from suppliers: Some types of heavy-duty off-road equipment have product specifications and/or performance metrics established by the manufacturer. This data may be used to estimate the fuel consumption over the life of the product based on designed fuel consumption.

Engineering data: Types and step types, collectively referred to as "engineering data," allow companies to define reusable data structures and steps. AEM has identified these data streams as the third most mature in our guidance for heavy-duty off-road equipment. Data collected, such as test stand results, may provide estimates of fuel consumption in specific use cases and scenarios, which could be used to make assumptions for all applications.

Instrument field uses machine data to measure and monitor flow, level, pressure, temperature, and analyze liquids. Depending on the application, a field instrument may be used to measure and control different automation processes. AEM has classified this method of data collection as second-most mature, under telematics data. Analytical instruments provide important scientific data about manufactured products that serves to confirm that they operate as expected. These instruments run the gamut from simple apparatus to complex systems that combine a metrological function with software control. For the purposes of calculating scope 3 category 11 emissions, these streams can help estimate fuel consumption data.

Telematics data is the most mature data stream to use for fuel consumption. Although it may be difficult to obtain activity data from suppliers and other third parties in a reporting company's value chain, telematics can create data consistency between manufacturer and equipment owner. However, the variability presented by telematics data might also not be reflective of the fuel consumption throughout the estimated life of the machine for all machines.

The AEM/AEMP Telematics Standard was first published as ISO 15143-3 in 2016 by the International Organization for Standardization (ISO). The standard specifies the communication schema designed to provide mobile machinery status data from a telematics provider's server to third-party client applications via the Internet. There are limitations to telematics data, which may restrict companies from using this method. However, as technology and data aggregation tools become more sophisticated, there will be opportunities to use telematics data in more strategic ways, including for emissions reporting.

Limitations and solutions on how to use this data strategically are as follows:

Data Points	Notes	Purpose
Fuel consumption	Snapshots of average fuel consumption should be aggregated, as it may not be possible to obtain consistent data streams	
Innovation	New technologies will create gaps in data from lesser advanced products to more advanced products (new attachments, size of the machine changing, etc.)	
Component hours (winches, boom telescope, gear boxes)	OEMs determine one naming convention for components (especially for multiple)	Machine life
Average percent of capacity	Number of hours used in certain percentages. Need to delineate percentages. For cranes this would be critical lift determination.	Used for optimization and maintenance if used at high-capacity majority of hours
Alert and count for each time capacity is over 100%	Cumulative count (per day/lifetime – customers can set up calculations on their end) not part of telematics	Count of events
Low tire air pressure alert	Impact on emissions is hours calculated for the 12-month period. Includes periods of low tire air pressure.	Count of events
Anemometer – wind speed	Average wind speed for defined increment? Possibly include max wind speed.	Trigger alert for and impact efficiency of sprayer, crane, etc.
Boom extension %	Similar to average percent of capacity, but with boom extension as percentages of total boom length allowed	To determine utilization (best use, not too big/small). Combines, sprayers, etc.
Shock loading	Data not yet available	

Figure 7: ISO 15143-3 (formerly the AEM/AEMP Telematics Standard). In January 2020 an update to the standard was published.

Real-time telematics data points are not commonly assessed by all AEM member companies. The technology has not been widely adopted and may not exist in some cases. Therefore, in addition to explaining a real-time data application, AEM also finds it relevant to discuss the high, medium, or low-level accuracy of 12-month averages. This will include everything in between, where some real-time data may be used in conjunction with averages.

Depending on the data provider and end user agreement, data updates and new data sent can also vary. AEM recommends reviewing data agreements where applicable to determine hours of use and 12-month average calculations.

Energy Emissions Factor

The EPA has provided the *GHG Emissions Factor Hub*[10]. The document on the EPA website was designed to provide organizations with a regularly updated and easy-to-use set of default emission factors for organizational greenhouse gas reporting. https://www.epa.gov/system/files/documents/2023-03/ghg_emission_factors_hub.pdf

Another emissions factor database is housed with the International Energy Agency (IEA)[11]. The emissions factors database includes indicators related to emissions from electricity and heat generation.

AEM recommends utilizing these available tools, which can help simplify both the data aggregation and reporting functions within enterprises.

GHG Protocol and U.S. EPA work together, one referencing the other for key parts of calculating emissions. For example, the following link is to the EPA site for greenhouse gas overview. Listed on the site is an explanation of what greenhouse gases are and total U.S. Emissions in 2021 in million metric tons of CO_2 equivalent (MMTCO2e): https://www.epa.gov/ghgemissions/overview-greenhouse-gases.

Treatment of Upstream Emissions from Energy Consumption

Life cycle assessment will encompass a company's goals, inventory analysis, impact assessment, and data interpretation. What these mean to a particular company may influence when it starts and stops measuring specific emissions for scope 3 category 11 calculations. Keeping in mind category 11 emissions are usually measured "tank-to-wheel" or TTW, one can dive into the nuance of how worksite activities can impact how energy consumption is measured.

With respect to the energy consumed by a product, experts have decided that it comes down to a consideration of three options: tank-to-wheel, well-to-wheel, or cradle-to-grave. According to the U.S. Department of Energy, definitions for these methods of measuring emissions are as follows:

Tank-to-wheel refers to a part of the energy chain of a machine that extends from the point at which energy is absorbed (charging point, fuel pump) to discharge (being on the move). TTW thus describes the use of fuel in the machine and emissions during driving. However, in practice, using a diesel generator to charge a battery-electric dozer can create complexities when measuring category 11 emissions from battery electric equipment. This is one example of how many companies may find the consideration of upstream emissions an important part of their use phase emissions.

Well-to-wheel GHG emissions include all emissions related to fuel and energy production, processing, distribution, and use. In the case of gasoline, emissions are produced while extracting petroleum from the earth, refining it, distributing the fuel to stations, and burning it in machines. According to the GHG Protocol, this measure includes upstream emissions and is a consideration for products that directly consume electricity.

<table>
<tr><th>Options to measure energy consumption</th><th>Products that directly consume fuel</th><th>Products that directly consume electricity</th></tr>
<tr><td>Tank to Wheel</td><td>Required, per GHG protocol</td><td rowspan="2">Required, per GHG protocol</td></tr>
<tr><td>Well to Wheel</td><td>Optional, per GHG protocol</td></tr>
</table>

Figure 8: Treatment of upstream emissions from energy consumptions

Either TTW or WTW may be represented based on the emissions factor used (many of which are sited in this document).

Cradle-to-grave emissions include all emissions considered on a well-to-wheel basis, as well as machine-cycle emissions associated with machine and battery manufacturing, recycling, and disposal. Careful consideration should be given to choosing one of these methods above. Depending on a company's goals, these different forms of calculations could impact the outcome.

Verification

Important aspects of an ESG risk assessment are the impact assessments and third-party auditors/verification which provide assurance for data reported. According to the GHG Protocol for category 11, "Ideally agreement should be reached by a sector (e.g., industry associations and trade bodies) on common rules for use phase assumptions. These assumptions can then be verified by an independent third party to improve consistency and comparability."

Combustion emissions factors of fuel, as detailed throughout this guidance document, are needed for calculation of GHG emissions from different areas. AEM recommends companies seek third-party assurance for their data and consider the complexities of maintaining accurate data in their inventories.

Summary

In summary, Off-Road Greenhouse Gas Protocol for Scope 3 Category 11 shares additional guidance on the Greenhouse Gas Protocol Initiative (GHGPI) as it pertains to the manufacturers of heavy-duty off-road equipment. The primary objective is to create uniformity and harmonization among companies attempting to monitor, track, and report phase Scope 3 Category 11 emissions. The document uses the GHGPI's standardized framework to measure and manage GHG emissions, but tailors it to the heavy-duty off-road equipment industry, leveraging the collective expertise of AEM and its members. In addition to providing a background about Scope 3 Category 11 emissions of sold products, Off-Road Greenhouse Gas Protocol for Scope 3 Category 11 shares several other relevant considerations and recommendations for heavy-duty off-road equipment manufacturers: product definitions, value chain GHG emissions boundaries, necessary principles on how to calculate emissions (including the various data requirements and how they can be derived), and the verification process of measurement and reporting.

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[1] AEM is the North American-based international trade group representing heavy-duty off-road equipment manufacturers and suppliers with more than 1,000 member companies and over 200 product lines in the construction, agriculture, mining, forestry, and utility industries. The equipment manufacturing industry in the United States supports 2.8 million jobs and contributes roughly $288 billion to the economy every year. Our industries remain a critical part of the U.S. economy and represent 12% of all manufacturing jobs in the United States. Our members develop and produce a multitude of technologies in a wide range of products, components, and systems that ensure heavy-duty off-road equipment remains safe and efficient, while at the same time reducing greenhouse gas emissions and environmental impacts. Finished products have a life cycle measured in decades and are designed for recycling or remanufacturing of the entire product at the end of life. Additionally, our industry sectors strive to develop climate-friendly propulsion systems and support robust environmental stewardship programs around the world.

[2] See GHG Protocol, Required Greenhouse Gases in Inventories: Accounting and Reporting Standard Amendment (Feb. 2013), available at https://www.ghgprotocol.org/sites/default/files/ghgp/NF3-Amendment_052213.pdf.

[3] World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). *Technical Guidance for Calculating Scope 3 Emissions*: Accounting and Reporting Standard Amendment (Feb. 2013), available at https://ghgprotocol.org/sites/default/files/standards_supporting/Chapter11.pdf. Pg 114.

[4] Determine Organizational Boundaries. (Last updated Dec. 6, 2022). https://www.epa.gov/climateleadership/determine-organizational-boundaries

[5] Processing End-of-Life Vehicles: A Guide for Environmental Protection, Safety and Profit in the United States-Mexico Border Area. July 2017 https://www.epa.gov/sites/default/files/2020-10/documents/eol_vehicle_guide_final_english.pdf

[6] See EPA, Emission Factors for Greenhouse Gas Inventories, available at https://www.epa.gov/climateleadership/ghg-emission-factors-hub.

[7] In Feb. 2013 the GHG Protocol amended the required greenhouse gas inventory list to align with the seven gases required by the Kyoto Protocol (consistent with the proposed definition of greenhouse gases). See GHG Protocol, Required Greenhouse Gases in Inventories: Accounting and Reporting Standard Amendment (Feb. 2013), available at https://www.ghgprotocol.org/sites/default/files/ghgp/NF3-Amendment_052213.pdf. Nevertheless, the GHG Protocol's Corporate Accounting and Reporting Standard, which was updated in 2015, continues to refer to only six greenhouse gases. We believe the common understanding of the GHG Protocol's Corporate Accounting and Reporting Standard is that the earlier amendment (reflecting seven gases) applies despite the subsequent 2015 update to the standard.

[8] See EPA, Emission Factors for Greenhouse Gas Inventories, available at https://www.epa.gov/climateleadership/ghg-emission-factors-hub.

[9] Rochester Institute of Technology's Golisano Institute for Sustainability. Golisano Institute for Sustainability (GIS) is a global leader in sustainability education and research. Drawing upon the skills of more than 100 full-time engineers, technicians, research faculty, and sponsored students, it operates six dynamic research centers and over 84,000 square feet of industrial infrastructure for sustainability modeling, testing, and prototyping. https://www.rit.edu/sustainabilityinstitute/blog/what-remanufacturing

[10] EPA Center for Corporate Climate Leadership. GHG Emission Factors Hub. April 7, 2022. https://www.epa.gov/climateleadership/ghg-emission-factors-hub

[11] International Energy Agency. Emissions Factors 2022. https://www.iea.org/data-and-statistics/data-product/emissions-factors-2022