# Greenhouse Gas Emissions: A Case Study of Development of Data Collection Tool and Calculation of Emissions

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## ABSTRACT

The absence of federal greenhouse gas (GHG) regulation in the United States has not diminished the importance of businesses assessing their impact on global climate change. Growing concern among shareholder and investor groups has motivated many organizations to quantify their greenhouse (GHG) emissions and commit to GHG reductions. Accurate quantification and detailed documentation of GHG emissions data enables a company to demonstrate transparency and enhance the credibility of its corporate climate change strategy. Establishing a comprehensive corporate GHG inventory is an important first step in developing a climate change strategy. However, conducting a baseline corporate GHG inventory can be a challenging process, particularly with respect to data gathering and data validation.

This paper will present a general approach for preparing the inventory with case study in conducting a baseline GHG inventory using Environmental Management Information Systems (EMIS). The paper will present best practices in establishing the organizational and operational boundaries of a corporate GHG emissions inventory, conducting data collection and data validation process using an EMIS, completing the calculation procedures, and establishing appropriate performance metrics. In addition, methods for improving data quality and integrating the GHG inventory with energy management systems will be presented. Finally, the paper provides guidance on continuous improvement and maintenance of the GHG inventory.

## INTRODUCTION

The management of GHG emissions requires accurate quantification of these emissions. The corporate GHG initiatives undertaken by companies are most successful if defined protocols are followed. The protocol guidance can be derived from one of the several protocols published by U.S. EPA, state registries, or established research and focus groups. Based on cumulative guidance derived from these protocols, an organization can also develop and implement a custom GHG inventory protocol that meets their business needs. A custom GHG protocol is useful in that it provides an internal guideline to the organization which is highly specific to the organization and addresses unique assumptions or approaches used by the organization.

This paper presents the GHG emissions inventory development process followed by a case study that demonstrates the implementation of the process. The companies prepare GHG inventories due to shareholder resolutions that require them to evaluate the emissions footprint. An analysis of company-wide GHG emissions also assists companies to consolidate responses to numerous stakeholders. Certain proactive companies also take initiatives to calculate GHG emissions in the light of future regulatory developments.

Resources are essential to the development of a GHG inventory, and companies should ensure that the effort is appropriately staffed with experienced individuals. To ensure relevance of the inventory, the project team first identifies all facilities and emission units within the organizational and operational boundaries of the inventory. A well-defined protocol and guidance is then created to implement the inventory development process. Based on the number of facilities and goals of inventory, an EMIS tool can also be developed and used to collect data and/or perform calculations. Once the GHG emissions are calculated, the results can be appropriately analyzed and presented on a facility, business unit, division, and corporate basis as well as by type of emissions source and gas. The GHG emissions footprint can then be used to develop future GHG reduction targets and prioritize efforts. Since the regulatory developments related to climate change are very dynamic, the companies must also track regulatory developments in all countries and states where the affected facilities are located. The results of these developments must be conveyed to the top management to coordinate future efforts or adjust the strategy, as necessary.

The complete GHG inventory process is further examined within this paper in the context of a case study GHG inventory for a global general manufacturing company. The lessons learned from preparing the inventory are also presented.

## GHG EMISSIONS INVENTORY DEVELOPMENT PROCESS

The GHG emissions inventory development process consists of steps that are discussed in following sections. Each step starting from understanding the importance of the inventory to establishing future reduction targets should be followed to prepare an accurate inventory and derive the maximum benefit from this initiative.

### Educating Decision Makers

Successful implementation of a GHG emissions inventory program starts with educating the executive management regarding the relevant issues at hand. In the U.S., there are numerous regulatory developments associated with climate change at both the state and federal regulatory level that need to be closely tracked by organizations. In particular, state level activity is much more dynamic. Federal bills associated with climate change are ever-increasing, although at a less rapid pace than state regulatory developments. (As an example, California is among the states that are taking drastic action on the climate change issue, with a mandate to reduce GHG emissions to 1990 levels by 2020. It is noteworthy that this regulatory requirement developed rather quickly, within only approximately a one year time period. At present, many companies are struggling with mapping out their operational strategies in California, with a looming and rather aggressive mandatory GHG reporting and reduction requirement on the horizon.)

The management must also understand the importance of stakeholders request to demonstrate company’s climate change action policy. Many companies have received shareholder resolutions on climate change and other companies have received similar inquiries. This trend regarding shareholder engagement on the climate change issue is not diminishing. Increasingly, companies are in the position of having to carefully manage every response to shareholders or other stakeholders to ensure that the company is conveying a consistent and accurate message regarding their position on climate change.

The most successful programs will have top-down support from the highest levels of the company and will often have an internal ambassador or champion of the climate change program. This provides visibility on the issue to operations staff and also highlights the importance of the program. The visibility can help drive the inventory project forward, particularly with facility-level personnel who are relied upon to collect much of the data.

## Principles of Reporting

The World Resources Institute/ World Business Council for Sustainable Development (WRI/WBCSD) GHG Protocol sets forth generally accepted GHG accounting principles.[1] The following reporting principles may be used as the basis crafting the GHG inventory details.

*Relevance*

The GHG inventory should appropriately reflect the GHG emissions of the company and serve the decision making needs of users, both internal and external to the company.

*Completeness*

The GHG inventory should account for and report on all GHG emission sources and activities within the chosen inventory boundary. Exclusions should be disclosed and justified.

*Consistency*

The GHG inventory should use consistent methodologies to allow for meaningful comparisons of emissions over time. Changes to the data, inventory boundary, methods or any other relevant factors in the time series should be documented transparently.

*Transparency*

The GHG inventory should address all relevant issues in a factual and coherent manner, based on a clear audit trail. Relevant assumptions and appropriate references to the accounting and calculation methodologies and data sources used should be disclosed.

*Accuracy*

The GHG inventory should ensure that the quantification of GHG emissions is systematically neither over nor under actual emissions, as far as can be judged, and that uncertainties are reduced as far as practicable. In addition, the GHG inventory should achieve sufficient accuracy to enable users to make decisions with reasonable assurance as to the integrity of the reported information.

## Establishing Organizational and Operational Boundaries

### <u>Organizational Boundaries</u>

The guidance on setting organizational boundaries can be derived from the reference protocols that are generally accepted protocol for conducting GHG inventories.[1,2] The geographic scope of the GHG inventory must include all reporting facilities worldwide owned and operated by the company. There are typically two ways of reporting GHG emissions – by either the *control approach* or *equity share approach*.

*Control Approach*

According to the WRI/WBCSD GHG Protocol, a company should account for 100 percent of the GHG emissions from operations over which it has control. Control can be based on whether the organization has financial or operational control over the entity. For financial control reporting, the company would have financial control over the entity's operations with a view to gaining economic benefit from the activities. For operational control, a company has full authority to introduce and implement its operating policies at the operation. Governmental reporting and emissions trading programs are typically based on the operational control approach, since responsibility for compliance typically falls to the operator and not the equity holders of the entity.

*Equity Share Approach*

Equity share reporting is determined based on the percentage of financial interest that a company has in facilities or operations. Equity share reporting provides a more accurate allocation of risk and liability associated with GHG emissions and aligns with generally accepted financial accounting practices. However, obtaining information from facilities that are not wholly owned can be difficult and time consuming. For assessing financial risk, equity share reporting may provide a more accurate depiction of the companies GHG profile. However, it can result in higher administrative costs for inventorying emissions since it can be difficult to gather information from non-operated entities. Table 1 presents the percent of GHG emissions that are required to be reported in correspondence to different control levels of a company.

**Table 1.** Reporting Based on Control[2]

| **Level of Control** | **Percent of GHG Emissions to Report** |
|---|---|
| Wholly-owned | 100% |
| Partially owned with financial and operational control | 100% |
| Partially owned with financial control; no operational control | 0% |
| Partially owned with operational control; no financial control | 100% |
| Not owned but have a capital or financial lease | 100% |
| Not owned but have an operating lease | 100% |

Operational Boundaries

Operational boundaries delineate the scope for the types of operations and emission sources that are be included in the inventory. Scope 1, Scope 2, and Scope 3 emissions are defined based on the guidance provided in WRI/WBCSD protocol.

Scope 1 emissions are direct GHG emissions from sources that are owned or controlled by the company. Scope 2 emissions are indirect GHG emissions from purchased electricity, heat, or steam consumed but not directly generated by the facility. Scope 3 emissions are other indirect emissions which are a consequence of the activities of a company but are emitted from sources not owned or controlled by the company

In general, organizations are strongly encouraged to quantify Scope 1 and Scope 2 emissions, while Scope 3 emissions constitute a more advanced form of reporting. The decision to inventory Scope 3 emissions is mainly based on the industry sector. For most manufacturing companies, Scope 1 and Scope 2 emissions are most commonly tracked.

Table 2 provides a summary of the different types of emission sources, based on the general guidance contained in the WRI/WBCSD Greenhouse Gas Protocol.[1]

**Table 2.** Typical GHG Emission Sources[2]

| **Scope 1 – Direct Emissions (Owned or Controlled by the Company)** | **Scope 2 – Indirect Emissions (Not Owned or Controlled by the Company)** | **Scope 3– Other Indirect Emissions (Not Owned or Controlled by the Company)** |
|---|---|---|
| ▲ Stationary Combustion emissions from stationary sources (boilers, furnaces, heaters, ovens)<br>▲ Process Emissions – manufacture or processing of chemicals and materials, incinerator combustion of organic streams<br>▲ Transportation of materials, products, waste, and employees – combustion of fuels in company owned/controlled mobile combustion sources (trucks, trains, ships, airplanes, buses, and cars)<br>▲ Fugitive emissions – equipment leaks, HFC emissions during the use of refrigeration and air conditioning equipment | ▲ Emissions from purchased electricity, heat, or steam for own consumption. | ▲ Extraction and production of purchased materials and fuels<br>▲ Transport-related activities (transportation of purchased materials/fuels, employee business travel, employee commuting, transportation of sold products or waste<br>▲ Electricity-related activities (not included in Scope 2) – extraction, production and transportation of fuels consumed in the generation of electricity<br>▲ Leased assets, franchise, and outsourced activities – Scope 3 only if equity or control approach does not apply |

### Identify Facilities and Sources

After establishing the inventory boundaries, all facilities to be included in the inventory are identified. An accurate list of all facilities and sources within the inventory scope must be developed by the organization. The facilities may be included in this list based on the types of existing sources and their expected emissions contribution. Based on the spectrum of company's facilities that will be included in the inventory, the importance of EMIS tool for inventory development may be assessed. For future inventories, a process must also be established to identify new facilities or facilities that have been divested. Many companies are beginning to create GHG quality management procedures that include a mechanism for tracking changes in the facility and source list, as this becomes critical to creating an accurate GHG inventory and adjusting a baseline.

**Establish Guidance and Protocols**

Several GHG inventory development protocols are published by stated registries, U.S. EPA, and research and focus groups. The widely used protocols are listed as follows:

- The GHG Protocol, A Corporate Accounting and Reporting Standard (Revised Edition), World Business Council for Sustainable Development and World Resources Institute, 2004.
- California Climate Action Registry General Reporting Protocol, Version 2.2, California Climate Action Registry, April 2007.
- U.S. EPA Climate Leaders GHG Inventory Protocol, Core Module Guidance, October 2004.

There are numerous other sector-based guidelines and protocols that can also be used, depending on the sector. Again, many organizations prepare custom internal protocols in order to specify the appropriate elements of various protocols to their organization. This custom protocol can also be used as an internal guiding document that provides information on how the inventory will be conducted. It can also be efficiently used as a guiding document during the third-party verification process.

**Implement EMIS or Use Other Data Collection and Emissions Calculations Tools**

After identifying relevant sources and facilities and implementing guidance protocols, data is collected to perform emissions calculations. Based on the number and type of facilities that will be included in the emissions inventory, a determination can be made whether an EMIS tool will be developed and implemented to collect data and perform emission calculations. The types of EMIS tools available in market can be as follows:

- *Enterprise EMIS.* An off the shelf tool is bought and implemented for the company to meet the inventory needs; and
- *Custom EMIS.* Based on the specific needs, a custom tool is developed and implemented for the company. It is also possible that an enterprise EMIS is purchased from a vendor and then customized to meet the company needs.

Use of an EMIS tool for a GHG inventory provides the following advantages:

- *Communication.* EMIS tool can have features to send email notifications and reminders to the responsible parties. Therefore, the desired tasks can be completed on schedule and this enable efficient management of resources by corporate environmental staff.
- *Accessibility.* Since the EMIS tool is web-based, it can be accessed from virtually all locations worldwide. Therefore, it is easier for the corporate officials to report to the program and track progress of the program.
- *Versatility.* The EMIS tool can be integrated with other facility compliance functions and used as a multi-purpose tool. Therefore, once developed and implemented this tool can be used to perform other EH&S and corporate compliance functions.
- *Functionality.* The tool can be used to only collect data or collect data and perform emission calculations. Microsoft Excel® based custom report templates may also be set-up in the EMIS tool for use outside the EMIS system. (e.g., performing emissions calculations in Excel)
- *Flexibility.* The EMIS tool facilitates easy updates to emissions factors, changes to emissions calculations, and the addition or deletion of new facilities and/or sources. Finally, an EMIS tool can help a company report to various programs, both mandatory (e.g., the European Union Emissions

Trading Scheme) and voluntary (e.g., the California Climate Action Registry), as well as track compliance obligations for emissions credits, if that functionality is needed in the future.
- *Archiving.* An EMIS tool can also function as an historical archive for baseline emissions data. This will assist in comparing usage data across several years. Finally, EMIS tools typically include audit functions which allow for traceability of data that is revised or changed, which can be useful for the purposes of a third-party certification of data.

If using an EMIS for the full GHG inventory seems daunting, it is important to note that the EMIS tool can also be solely for the data gathering phase, as an initial step, and then utilize a spreadsheets to perform the GHG calculations Therefore, the chosen EMIS tool can have dual functionality – collect data or collect data and perform emission calculations. If the organization is new to using an EMIS system, facility personnel will typically require a training program to learn how to enter the GHG data.

**Data Collection and Validation**

For a number of reasons, organizations need to ensure that their GHG inventory does not significantly overestimate or underestimate emissions, particularly if regulations are adopted, since the emissions inventory may potentially be the basis for award of allowances. Therefore, accuracy needs to be assured in each stop of the GHG inventory process. The higher the accuracy of the GHG inventory, the more well positioned the company will be when regulations are adopted. Data validation and verification procedures are important since facility personnel may incorrectly enter data, use incorrect units, or apply incorrect conversions.

An EMIS system can help minimize data reporting errors, as there is the ability to lock units to certain selections rather than allow the facilities to enter their own units. An EMIS tool can also be configured to generate tabular reports for the data provided by all facilities. Based on analysis of these reports, the data gaps and potential errors are identified in the data entry process and these findings form the basis of further data collection efforts.

For organizations that have performed a GHG inventory for more than one year, a valuable second data validation step that can be conducted post-calculation is to compare emissions between years for each operation and also review production data to ensure that the emissions are accurately estimated and pass a primary logic test.

In order to minimize the errors in the data gathering process, a central e-mail database can be established to which the facility representatives could present their questions and issues. This may be essential if a corporate or second party team is conducting the GHG inventory development process. This email database can preclude potential problems with the data entry (if any) by facilities, serve as documentation for the guidance provided to facilities, and also support the data validation and verification effort.

**Quantifying Emissions**

GHG emissions can be quantified after complete data set has been collected. As part of Scope 1 and 2 emission sources, the GHG emissions are generated from:

*Scope 1 Sources*

- Stationary combustion (boilers, heaters, burners, etc.);
- Fleet vehicles;

- Process emissions (thermal oxidizers, selective catalytic reduction units, etc.); and
- Refrigerant losses.

*Scope 2 Sources*

- Indirect emissions associated with purchased electricity, heat, or steam.

For manufacturing facilities, the primary contributions to GHG emissions typically result from stationary combustion sources (boilers, heaters, burners, etc.), purchased electricity, and industrial processes. The six (6) GHGs that have to quantified are carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), hydrofluorocarbons (HFC), perfluorocarbons (PFC), and sulfur hexafluoride ($SF_6$).

$CO_2$ equivalent (or $CO_2e$) is calculated by converting non-$CO_2$ GHG emissions to $CO_2e$ using the relative global warming potentials (GWPs) of the individual GHGs. It is advised to use the GWPs contained in the Intergovernmental Panel on Climate Change (IPCC) Second Assessment Report (SAR). Table 3 lists the GWPs for the GHGs of concern.

**Table 3.** Global Warming Potentials based on Intergovernmental Panel on Climate Change's (IPCC) Second Assessment Report (SAR)

| GHG | 100-year GWP |
|---|---|
| $CO_2$ | 1 |
| $CH_4$ | 21 |
| $N_2O$ | 310 |
| Hydrofluorocarbons | 140-11,700 |
| Perfluorocarbons | 6,500-9,200 |
| Sulfur Hexafluoride | 23,900 |

Direct Emissions from Stationary Combustion

To calculate the GHG emissions from the combustion of fossil fuel in the stationary combustion units, fuel usage is obtained from the reporting facilities. This data is based on the actual usage. Fuel usage data can be compared with the fuel derived from maximum heat capacities of individual emissions units to validate the data.

For the case study inventory, direct stationary combustion emissions ($CO_2$, $CH_4$, and $N_2O$) are calculated using the emission factors developed by the CCAR.[2] For illustration purposes, Figure 1 represents the emission calculations for $CO_2$ and $CO_2e$ from $CH_4$ and $N_2O$ emissions. $CH_4$ and $N_2O$ emissions are calculated using a similar methodology as $CO_2$ emissions.

**Figure 1.** Calculation of Direct GHG Emissions from Stationary Combustion

| | | |
|---|---|---|
| $CO_2$ Emissions (metric tons) | = | $CO_2$ Emission Factor (kg/UOM) x Usage (UOM) x 0.001(metric tons/kg), *Note:* UOM – Units of Measure |
| Total Carbon Dioxide Equivalent ($CO_2e$) | = | [$CH_4$ Emissions (metric tons) x $CH_4$ GWP] + [$N_2O$ Emissions (metric tons) x $N_2O$ GWP] + $CO_2$ Emissions (metric tons) |

Direct Emissions from Fleet Vehicles

Mobile source GHG emissions are mostly calculated for fleet vehicles that are owned and operated by the companies (Scope 1 emissions). To calculate the GHG emissions from the combustion of fossil fuel in the fleet vehicles, fuel usage information or vehicle miles traveled for each type of fleet vehicle at each facility is required. Through an EMIS, each facility can be requested to provide the vehicle make, model, and model year. Vehicle fuel usage is calculated based on the total miles traveled for each motor vehicle (or vice versa). The fuel usage can be calculated based on the vehicle miles traveled assuming a split of vehicle use as 55% in city and 45% on highway.[2]

$CO_2$ and $N_2O$ emissions calculation methodology is presented in Figure 2 for illustration purposes. $CH_4$ emissions are calculated using a methodology similar to $N_2O$ emissions.

**Figure 2.** Calculation of Direct GHG Emissions from Mobile Combustion Calculation Equations

| | | |
|---|---|---|
| $CO_2$ Emissions (metric tons) | = | $CO_2$ Emission Factor (kg/gallon) x Usage (gallon) x 0.001(metric tons/kg) |
| $N_2O$ Emissions (metric tons) | = | $N_2O$ Emission Factor (g/mile) x Annual VMT (miles/year) x 1.00E-6 (metric tons/g) |

Direct Emissions from Manufacturing Processes

A source that is often overlooked when conducting GHG emissions is the resultant process $CO_2$ emissions from the incineration of VOC streams using thermal oxidizers. Numerous manufacturing facilities use control equipment (thermal oxidizers, SCR, etc.) to control Volatile Organic Compound (VOC), Nitrogen Oxides ($NO_X$), and other emissions. For illustration purposes, the methodology to calculate GHG emissions from VOC combustion in thermal oxidizers is discussed in this section. In addition to GHG emissions from combustion of the organic stream, GHGs are also generated due to fuel combustion in the thermal oxidizer burners. It is typically most straightforward to account for the burner GHG emissions with the stationary combustion emissions.

To calculate $CO_2$ emissions from the combustion of the organic stream, facilities provide data on the primary VOC constituent's combusted and the thermal oxidizer input stream characteristics. The $CO_2$ emissions are calculated based on the VOC stream analysis using the following formulas.[3] Figure 3 represents the GHG emissions calculation methodology from thermal oxidizers.

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**Figure 3.** Calculation of Direct GHG Emissions from Manufacturing Processes

| | | |
|---|---|---|
| Total moles of gas steam per $ft^3$ | = | Gas stream pressure (atm) / {Gas stream temperature (°R) x Universal gas constant (0.7302 atm. $ft^3$/mol.R)} |
| Number of moles of $component_i$ | = | Total moles of gas steam per $ft^3$ x Mole % of component i |
| Weight of C per $ft^3$ of gas stream for $component_i$ | = | Molecular weight of $component_i$ (lb/lbmol) x Number of moles of $component_i$ x Weight % carbon |
| Total Weight of C per $ft^3$ of gas stream | = | $\sum_i$ Weight of C per $ft^3$ of gas stream for $component_i$, i – 1 to 5 |
| $CO_2$ Emissions (metric tons) | = | Emission Factor (lb C/ $ft^3$) x Gas stream flow rate ($ft^3$/year) x 100% x Molecular weight of $CO_2$ (44 lb/lbmol) x 453.6 (g/lb) x 1.00E-6 (metric tons/g) / Molecular weight of C (12 lb/lbmol) |

Direct Fugitive Emissions

Hydrofluorocarbons (HFCs) are often used in refrigeration systems and are generated from the charging and recharging of air conditioning systems, particularly motor vehicle air conditioners. To calculate HFC emissions from the refrigeration systems, facilities provide data for the type of air conditioning/chiller system (e.g., commercial air conditioning system, commercial chillers, etc.), number of such systems, and the refrigerant type. To calculate HFC emissions from refrigerant loss activities and streamline the GHG inventory process, upper bound annual loss rates and typical refrigerant charges from the CCAR General Reporting Protocol are utilized.[2] Through this methodology, facilities do not have to use a more complicated methodology, which involves use of a comprehensive mass balance approach.

HFC emissions are calculated using the following equations for each refrigeration system and refrigerant type. The HFC emissions from all the systems are aggregated to estimate the total HFC emissions from the facility and the corresponding $CO_2e$. Figure 4 represents the GHG emissions calculation methodology from refrigeration systems.

**Figure 4.** Calculation of Direct Fugitive GHG Emissions from Refrigeration Systems

| | | |
|---|---|---|
| Fugitive HFC Emissions (metric tons) | = | Number of systems x refrigerant charge per system (kg) x Upper bound loss rate (%) x 0.001(metric tons/kg) |
| Carbon Dioxide Equivalent ($CO_2e$) | = | HFC Emissions (metric tons) x HFC GWP |

Indirect Emissions from Purchased Electricity Use

To calculate GHG emissions from purchased electricity, the facilities provide the electricity usage data for baseline calendar year. For U.S. facilities, the adjusted average electricity emission factors, by state and region, contained in the CCAR General Reporting Protocol to calculate the $CO_2$, $CH_4$, and $N_2O$ emissions may be used. For international facilities, the emission factors published by International Energy Agency are used.[2] Figure 5 represents the emissions calculation methodology for calculating indirect GHG emissions due to electricity usage.

**Figure 5.** Indirect GHG Emissions from Electricity Use

| | | |
|---|---|---|
| $CO_2$ Emissions (metric tons) | = | Annual electricity usage (kWh) x Emission factor (metric tons/MWh) x 0.001( MWh/kWh) |

## De Minimis Emissions

De minimis emissions can be identified in parallel with identifying significant emitters. When inventorying GHG emissions, it is important to ensure that a majority of material emissions are included in the inventory. This can be accomplished by setting a de minimis or materiality threshold. For example, a de minimis threshold of 5 percent would mean that the inventory accounts for 95 percent of emissions and that the remaining 5 percent of emissions from one or more sources (or one or more gases) are immaterial. This materiality threshold is important because tracking of small sources may be unduly burdensome and not cost-effective.

For this emissions inventory, a 5% de minimis threshold can be used to qualify the material emissions. Establishing a 5% de minimis threshold will streamline data gathering efforts for future years. For those sources or gases that potentially fall within the de minimis threshold, emissions may not be calculated in the future (unless the underlying assumptions used to calculate emissions from these sources change materially).

## GHG Emissions Baseline Tracking

A baseline is a datum or reference point against which to measure GHG emissions performance over time. The baseline allows a company to assess if overall GHG emissions are increasing or decreasing from year to year. In the United States, baselines are commonly used for voluntary emission registries, such as the California Climate Action Registry or the DOE 1605(b) registry. For each registry, the rules may be different with regard to how the baseline year is calculated and when the baseline year is recalculated.

In general, a company can select any year after 1990 as a baseline year. International companies often choose the baseline year of 1990, since it coincides with the reduction targets negotiated under the Kyoto Protocol. In addition, many northeastern states in the U.S are setting GHG reduction targets based on 1990 levels. Often, a 1990 baseline is selected for alignment with the Kyoto Protocol. However, it should be noted that the Kyoto Protocol applies to countries not companies, and not all countries will require reporting of 1990 emissions from organizations to demonstrate attainment of Kyoto Protocol targets. In general, it is recommended that the base year emissions data be verifiable and consistent, which may be challenging for a baseline year as early as 1990.

The GHG emissions baseline for a company will remain static from year to year and will only be adjusted to reflect structural changes in the organization, such as sale of a facility to another company or acquisition of another company. When structural changes occur, the baseline will be adjusted in order to ensure that measured increases or decreases are the result of organic increases or decreases in manufacturing levels or energy intensity, rather than increases or decreases associated with acquiring and selling companies.

### GHG Intensity Metrics

In addition to setting a baseline and comparing aggregate GHG emissions from year to year, GHG intensity metrics can be a useful tool for comparing operations and evaluating efficiency. GHG intensity metrics are normalized emissions based on production or economic output. Therefore, the units of these metrics differ from one industrial sector to another. Effective intensity metrics help track significant developments and their impact on GHG emissions in the organization.

### Emission Reductions

The above steps lead to the development of a company wide GHG emissions inventory. Based on the evaluation of these emissions, a company can identify significant emitting facilities and sources. Therefore, future emissions reduction targets can be established and reasonable efforts can be structured. GHG emission reduction opportunities may include, but not limited to, the following:

- *Energy Conservation and Efficiency*. This includes improving the efficiency of lighting systems, HVAC systems, electric motors, compressed air systems, and steam systems.
- *Process Improvements and Operational Changes.* Process and operational changes are often more challenging. This may include reducing the energy demand of key process equipment and reducing the waste flows that directly/indirectly result in GHG emissions. For example, in order to minimize methane emissions, methane emissions may be flared or captured.
- *Cleaner and Renewable Energy*. This may include fuel switching, cogeneration, use of fuel cells, and use of renewable energy.
- *GHG Offsets*. Some companies purchase external GHG emissions offsets in the voluntary carbon market to mitigate their GHG profile.

## CASE STUDY OF CALCULATING GHG EMISSIONS FOR A GENERAL MANUFACTURING COMPANY

A comprehensive GHG emissions inventory was developed for a general manufacturing company that operates 100+ facilities in several countries across several business divisions. An EMIS tool was also utilized for data collection tasks while preparing the emissions inventory. The same principles that were previously discussed in this paper were applied to this GHG inventory.

- **Educating the Decision Makers.** The executive management of this company understood early in the process why the GHG emissions inventory was necessary. The emissions inventory development initiative was taken by this company primarily due to a shareholder’s resolution. In addition, the organization also understood that a comprehensive emissions inventory would help in the company’s increasing sustainability focus and would consolidate climate change information for provision to numerous stakeholders.

- **Establishing a Reporting Basis.** Organizational boundaries were established for the inventory using the *control approach*. Only emissions from facilities that were under operational control by the company were included in the inventory. While establishing operational boundaries, it was decided that only *Scope 1* (direct emissions from company owned emission sources) *and 2* (indirect emissions from electricity, heat, or steam purchase and use) emission sources would be included in the inventory. The geographical scope of the inventory was also established to include all U.S. and international facilities. Emissions from leased facilities were included only if the lease was under the company's name. For example, GHG emissions from fleet vehicles that were under personal lease were not included in the inventory.

- ▲ **Identifying Facilities and Emission Sources.** The key GHG emission contributing sources at the listed facilities were identified. These sources included the direct emissions sources, such as stationary combustion units, fleet vehicles, thermal oxidizers, and refrigeration and air conditioning systems. Indirect emissions due to electricity usage were also included in the emissions inventory.

- ▲ **Establishing Protocol.** Before initiating the emissions inventory development process, it was important to finalize the emissions calculation methodology for each emissions source type. The emissions calculation methodology depended on the selected guidance protocol. Due to the availability of several guidance protocols, this company decided to prepare its internal custom GHG inventory protocol that derives relevant information from the aforementioned different protocols (WRI/WBCSD, CCAR GHG Protocol, and EPA Climate Leaders). The custom GHG protocol was reviewed and agreed upon by all parties involved before proceeding with the inventory. In the future, this custom GHG protocol may be used as a reference if the emissions inventory is evaluated by a third-party verifier.

- ▲ **Implementing EMIS, Validating Data, and Quantifying Emissions.** An EMIS tool was designed and implemented for this company to collect the relevant data. The EMIS tool provided a central web-based access to all responsible parties and streamlined the data collection effort. All facilities were included in the EMIS tool and several data entry forms were developed for each emissions source category.

  In coordinating with the facilities on data entry, a list of responsible persons and their contact information at each facility was obtained from the company's corporate environmental department. Adequate training was provided to all users regarding the use of the tool. Since the facilities were represented throughout the world, several on-line training webinars were also conducted.

  After data was collected using EMIS, data was validated to identify missing and incorrect data. The GHG inventory used a three step process for data validation.

  - First, at the onset of the inventory, the data reports were analyzed periodically while data was being collected. This step assisted in identifying the missing and incorrect data (very high values and incorrect units).
  - Next, emissions were calculated from all listed facilities using the data reports generated from the EMIS tool and developed spreadsheet templates. Custom report templates were also designed so that the data input into the EMIS could be easily checked, summarized, and then used in the emissions quantification process. These report templates reduced the time to complete emission calculations and increased the accuracy and efficiency of the inventory.
  - Finally, data reports were analyzed while performing calculations. This step assisted in comparing the emissions footprint of each facility with other similar facilities. Emissions calculations were revised based on the revised data provided by these facilities.

## CONCLUSIONS

The use of EMIS tool can be extremely useful in the development and maintenance of a GHG emissions inventory. The EMIS tool can provide continuous web-based access to the data and responsible parties in the organization can then track progress of the GHG emissions inventory initiative. EMIS tools can also be structured to archive historical usage data and send notifications and reminders to perform necessary tasks for preparing a GHG emissions inventory. Raw and custom reports can be generated in an EMIS tool that enables users to analyze data and then perform emissions calculations. Companies will be preparing and analyzing the GHG emissions inventories on an annual basis, and an EMIS tool can be extremely useful in the process of conducting a worldwide GHG emissions inventory and achieving third party verification of the inventory.

Important lessons learned while preparing a baseline inventory can be utilized to increase the efficiency of emissions inventory initiatives in future years. The development of a custom GHG protocol for a company can establish the basis for the emissions inventory and serve as a guiding document for third party verification. An accurate emissions inventory can be prepared by following rigorous data validation and verification procedures that are performed at multiple stages during the inventory development process. Comprehensive analysis of an emissions inventory also assists companies to structure future reduction initiatives that are relevant to the business needs of the organization.

## REFERENCES

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## KEY WORDS

Greenhouse Gases
Emissions Inventory
Environmental Management Information Systems (EMIS)
Baseline GHG Inventory