# Estimating Greenhouse Gas Emissions and Determining Carbon Footprint

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## BACKGROUND

Climate Change is a major buzzword in the media, among politicians, and the public these days. People across the globe have expressed concern and are demanding that governments address this issue. Companies “ahead of the curve” have realized many financial benefits of addressing climate change, such as reduced operating expenses, potential revenue source, enhanced product sales, stakeholder satisfaction, etc.

Many companies are addressing the overall issue of “sustainability” and other aspects of corporate social responsibility. However, there is much debate about what actions are positive as far as these matters are concerned. There have been accusations that some actions while positive in some aspects may either minor in the scheme of things or are negative in other aspects. There have been accusations of “greenwashing”. More companies are examining closely climate change because it has an accepted, undeniable metric (reduction of greenhouse gas (GHG) emissions) which is believed by the majority of the world’s scientific community to contribute significantly to climate change.

Finally, governments are addressing the growing public demands for action on this issue by promulgating rules impacting industries. As this is written, there is currently one federal regulation in effect, 40CFR Part 98, requiring about 10,000 U.S. facilities in certain industrial categories, emitting more than 25,000 metric tons of GHGs per year, to accurately estimate and report GHG emissions. Data to estimate GHG emissions must be collected per the exact requirements of the rule beginning in calendar year 2010, with the first report issued to the USEPA, certified by a major corporate official for accuracy, by March 31, 2011, then by March 31 of each subsequent year for the previous calendar year. While this course will help companies required to estimate GHG emissions comply with Part 98, it is critical to review and follow the exact procedures found in the Part 98 rule to assure and maintain compliance.

Congress is currently debating a climate change bill which will require reductions in overall GHG emissions. The bill is expected to contain both mandatory GHG emission reduction limits and incentives (cap and trade) to achieve this. On the regional level, ten Northeast states have banded together to enforce a rule called the Regional Greenhouse Gas Initiative (RGGI), requiring power plants in these states to cumulatively reduce their GHG emissions through a cap and trade system of carbon credits. Finally, the State of California is in the process of passing stringent GHG emission reduction rules and incentives across many industrial categories called AB-32, to go into effect in 2012. Other states are watching and have hinted they may promulgate many or all of the AB-32 rules in their states. Therefore, more facilities will likely need to estimate and manage their GHG emissions.

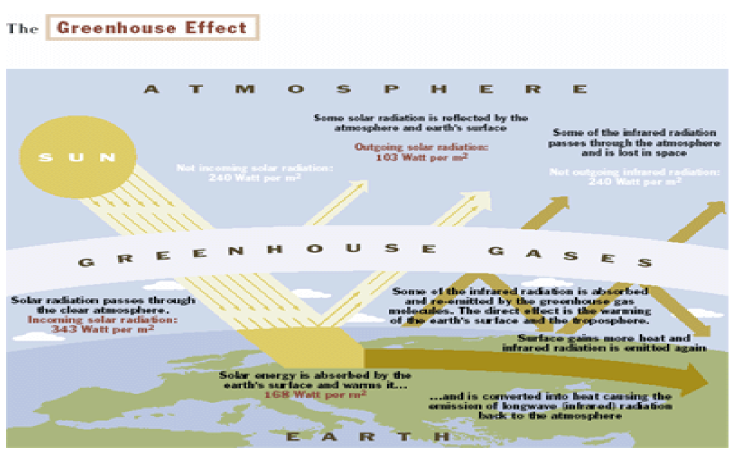
As such, companies have taken notice that through financial benefits and future regulation, climate change through GHG emission reduction should be addressed beginning with a GHG emissions inventory, a “snapshot” of your company’s GHG emissions. Of course, one cannot manage and reduce GHG emissions without first accurately estimating them. Another course offered by CEDengineering.com titled: *“Implementing a Climate Change Program” (Course No. C02-012)* discusses how to best organize a climate change program, its benefits, and the different technical expertise involved. Consequently, it is the engineer that must lead the way to make progress in terms of estimating and managing GHG emissions in approved manners at the corporate and facility levels. A GHG emissions inventory is also often known as one’s “carbon footprint”; although there are slight differences between these terms (discussed herein). This course will review the basics of the accepted methods to estimate GHG emissions and how to determine and use one’s carbon footprint.

## WHAT ARE GREENHOUSE GASES?

Greenhouse gases (GHGs) are a series of compounds that have the capability of absorbing infrared (IR) radiation, releasing the energy as heat. Radiation from the sun heats the earth’s surface, and in some cases, is converted to less intense radiation (IR) and released into the atmosphere. Most of the IR radiation goes through the atmosphere and into outer space, but as radiation collides with these GHGs naturally found in our atmosphere, heat is retained. Our atmosphere has always contained GHGs. One scientist estimated that if our atmosphere contained no GHGs, the average global temperature would be about -4°F. The problem, scientists believe, is that our atmosphere now has a higher concentration of GHGs than ever before. See Figure 1 below for an illustration.

Figure 1 - Illustration of the Greenhouse Effect

from the Pew Center on Global Climate



The main GHG of concern is carbon dioxide ($CO_2$). According to studies of air trapped in glaciers, the concentration of $CO_2$ in our atmosphere has stayed steady at about 280 ppmv for many millennia, rising or lowering perhaps by no more than 1 or 2 percent for brief periods. Currently, the global $CO_2$ concentration is about 385 ppmv, a rise of nearly 40% in just the last 130 years, correlating with the industrial revolution and our global, large scale combustion of fossil fuels. This rise also correlates with the average global temperature, which rose by about 1.1°F in the $20^{th}$ century. Therefore, while there is some scientific disagreement, most scientists around the world believe that there is a causal link between mankind's large-scale emissions of $CO_2$ and other GHGs with the measurement of global warming and physical threats of climate change. In addition, the majority of the scientific community believe that global warming and its physical threats can be reversed if GHG emissions are cut significantly in the next few decades; thereby reducing the atmospheric ambient concentration.

The United Nations Intergovernmental Panel on Climate Change (IPCC) has studied and gathered data on climate change for nearly 30 years. They are considered the international standard for understanding technical climate change issues. Their list of GHGs of concern:

- Carbon dioxide $CO_2$
- Methane $CH_4$
- Nitrous oxide $N_2O$
- Chlorofluorocarbons CFCs
- Hydrofluorocarbons HFCs
- Sulfur hexafluoride $SF_6$

It should be noted that another important GHG is water vapor. In fact, water is believed to contribute significantly to the normal greenhouse effect. However, atmospheric water vapor concentrations differ in different locations and are believed not to contribute to the current climate change problem.

By far, the GHG of concern with the highest ambient concentration is $CO_2$. As the ultimate product of the combustion of any fuel, $CO_2$ is emitted from many manmade activities more than the other GHGs.

The IPCC recognizes that not all GHGs have the same effect on absorbing IR radiation, trapping heat, and, therefore, potentially resulting in climate change. The IPCC has assigned global warming potentials (GWP) on each GHG to compare their relative effects. These GWPs take into consideration the amount of radiation the compound can absorb, the degree of heat given off, and its lifetime in the atmosphere. Table 1 below lists the GWPs of the common GHGs from the $4^{th}$ Assessment Report of the IPCC (2007).

Table 1 – Global Warming Potentials of Greenhouse Gases of Concern

| GHG | GWP |
|---|---|
| $CO_2$ | 1 |
| $CH_4$ | 25 |
| $N_2O$ | 298 |
| CFCs | 4,700 – 14,400 |
| HCFCs | 124 - 14,800 |
| $SF_6$ | 22,800 |

Note that the Kyoto Protocol and other climate change agreements use slightly different GWPs, based on older studies. The GWPs have changed as more research has been conducted. Yet these agreements did not aim to mandate re-calculating GHG emission reductions each time new sets of GWPs are published.

These GWPs are relative and on a mass basis. What this means is that reducing the emissions of 1 ton of $CH_4$ is equivalent (in terms of climate change) to reducing the emissions of 25 tons of $CO_2$. This is significant as it may be easier or more cost effective for a company to reduce 1 ton of methane rather than 25 tons of carbon dioxide for the same climate change effect. Taken to an extreme, reducing emissions of 1 *pound* of $SF_6$ is equivalent of reducing emissions of 11.4 *tons* of $CO_2$.

How does a company put together its total GHG emission reductions if GHGs are defined by this group of compounds; all with different effects? The standard "currency" of GHG emissions is called carbon dioxide equivalents or $CO_2e$. This is performed by summing the quantity of $CO_2$ emissions, the quantity of $CH_4$ emissions and multiplying it by 25, the quantity of $N_2O$ emissions and multiplying by 298, etc. to get $CO_2e$.

Example – A facility measures emissions of 42,438 tons of $CO_2$, 56 tons of $CH_4$, 89 tons of $N_2O$, 9.4 tons of HFC-23 (GWP of 14,800), and 8.9 tons of $SF_6$. What is the total emission rate in tons $CO_2e$? Which GHG contributed the most?

Answer: 48,438 + (56 x 25) + (89 x 298) + (9.4 x 14,800) + (8.9 x 22,800) = 418,400. $SF_6$ contributed the most $CO_2e$ emissions (202,920 tons $CO_2e$), even though it had the lowest total emission rate by weight.

Note: Emissions in the example here are given in (short) tons, the unit commonly used in the U.S. Globally, such emissions are provided in metric tons or tonnes. A metric ton equals 1,000 kilograms or 1.1 short tons.

## SOURCES OF GHG EMISSIONS

A company may have potentially many sources of GHG emissions. Such sources may be different from sources involved in traditional air emission inventories. Some occur outside your plant's property line. While we are concerned with impacts from air emissions from a facility, climate change and GHG emissions has a broader impact. Therefore, we care more about all activities a company has control over, even if it is outside of the facility property line. An example of this is $CO_2$ emissions from company trucks travelling outside company property lines. It is owned and operated by the company and emits GHGs, but not in the traditional boundary we are used to. However, $CO_2$ emissions emanate from trucks on the facility property or assisting company operations that are owned and operated by other companies.

A second unique issue to determining which sources of GHG emissions to include in an inventory is the determination of direct and indirect emissions. What if your company performs operations in such a manner that it causes other entities to burn fuel or perform other operations that cause them to emit GHGs? This is indirect emissions. An example is electricity. While inserting the plug in the electric socket does not cause fuel to be burned or GHG emissions to occur at the socket or the facility (unless the facility generates its own electricity), this demand for electricity requires a power plant somewhere to potentially burn more fuel to create the needed electricity. Depending on what type of power plant generates the electricity, this would influence the degree of indirect GHG emissions.

As mentioned earlier, the federal regulation 40CFR Part 98 requires applicable facilities to gather data, estimate and report GHG emissions from certain processes. While a GHG emissions inventory of all processes that are under company control is preferred, compliance with this rule requires at the least addressing the listed applicable processes for each applicable industrial category.

The first step in estimating GHG emissions is to determine which GHG emitting processes you are in control of. Often this is referred to as determining one's "boundary". Which processes should you evaluate and which ones (which may emit GHG emissions) may not be included in the inventory? The World Resources Institute/World Business Council for Sustainable Development (WRI/WBCSD) has developed nomenclature to define the boundary.

- Scope 1 emissions are direct GHG emissions from your processes and facilities. These generally include fuel combustion equipment (i.e., boilers, electricity generators) and mobile sources (i.e., company-owned automobiles, trucks, etc.). Emissions may occur either within or outside your company's physical boundaries, but represent processes that the company has control over (what type of boilers or trucks used, what type of fuel they burn). The facilities need to identify all processes that directly emit any of the listed GHGs.

- Scope 2 emissions are indirect GHG emissions caused by your operations, such as purchased electricity and steam. While the example of electricity was discussed above, this can also apply to other utilities purchased from the outside, such as steam and chilled water. All indirect sources need to be identified.

- Scope 3 emissions are other indirect GHG emissions, mainly caused by the operations of your or other firms not directly under your control, but involved in making your product. These include such items as GHG emissions from the production of raw materials requested by your facilities, transportation of the raw materials to your facilities by outside trucking companies, delivery of the finished products to warehouses or stores, services that are contracted out to other firms, business travel, employee commutation, and others. Companies should at least identify which operations emitting GHGs fit the Scope 3 definition.

Most official registries of and programs for GHG emissions (voluntary and mandatory) require the company to prepare a complete GHG emissions inventory for Scope 1 and Scope 2 sources. Scope 3 is voluntary. Some companies choose to do portions of Scope 3 because of the availability of data (i.e., business travel records, truck travel usage records). Some choose to do portions of Scope 3 to raise the opportunities to reduce GHG emissions. However, most stay with just Scopes 1 and 2 emissions only as the boundary.

Now that the boundary is established, each facility or operation should develop a list of Scope 1 and Scope 2 GHG emitting operations or those necessary to demonstrate compliance with Part 98. For the former, this would typically include use of:

- different types of boilers or generators;
- different types of transportation equipment, such as company-owned cars, buses, trucks, etc.;
- different types of other mobile equipment, such as portable generators, lawn mowers, forklifts, etc.;
- electricity throughout the facility;
- steam;
- chilled water;
- air conditioning fluid (replacement for leaks).

## COLLECTING DATA FOR YOUR GHG EMISSIONS INVENTORY

Typically, once the boundary is established, the GHG emissions inventory (generally performed on the corporate level covering all facilities and operations) begins with an appropriate request for information necessary to perform the emission calculations. Such an information request can be done electronically by a database completed by facility managers remotely from their desks or can be done by paper or Excel spreadsheet. The various facility managers complete the questionnaire and submit it back for compilation and calculation of GHG emissions.

Data necessary for the major portions of a typical GHG emissions inventory are as follows:

- list of stationary combustion sources, including number and size of boilers, electricity generators, etc.
- fuel usage for these stationary sources (i.e., quantity of coal, natural gas, fuel oil, etc.)
- electricity purchases (usage)
- steam purchases (usage)
- usage of mobile sources (distance travelled or gasoline/diesel usage of company-owned automobiles, buses, trucks, airplanes, etc.)
- leakage of refrigerants that are listed GHGs
- if the company is including Scope 3 operations, then appropriate data such as number of trips and miles spent in business travel, operations by contractors and suppliers, etc.

While the list of sources and data needed appears to be appropriate only for manufacturing plants, all facilities controlled by a company should be included, even those that appear to emit little or no GHGs, such as offices or warehouses. An Excel spreadsheet or Word document is often used and distributed to appropriate employees at each facility to collect this information. Use of a standard format allows greater consistency and, if designed well, increases the chances of collecting quality data to estimate GHG emissions.

The most critical part of any GHG emissions inventory is data quality, as often raw data is not complete or accurate or the data entry person is unsure of how to interpret something or simply clicks the wrong box in the questionnaire. Although it appears that parameters like electricity and fuel usages are fairly straightforward (such as reading it off a bill or meter), it is usually not that simple. Does the electricity or fuel usage cover all processes? Are other processes captured in other bills or documentation? Are there multiple suppliers and therefore bills? Are they comparable? Are the correct units incorporated in the data entry of emission calculations or are they mixed between facilities?

Given that major decisions and investments may ride on the inventory, it is critical to devote significant resources to performing QA/QC on the data collected. Third-party verification is recommended, including at least spot reviews of the raw data from representative facilities. For entry into some programs, third-party verification is required. Again, data must be complete, accurate, and transparent. It is generally a good idea to send a followup questionnaire investigating the nature of the raw data.

## ESTIMATING GHG EMISSIONS

Once onsite data is collected, estimating GHG emissions is generally straightforward. Emission factors are typically used, although some agencies require $CO_2$ monitoring for large combustion sources. The "GHG Protocol", published by the World Resources Institute and World Business Council for Sustainable Development (WRI/WBCSD), contains specific emission factors for many different operations, such as combustion of different fuels from different types of equipment. The GHG Protocol also contains country-specific factors for electricity production based on the degree of usage of different fuels or non-combustion sources of electricity (i.e., nuclear, solar, wind, etc.). In addition, the U.S. Dept of Energy (USDOE) has region-specific GHG emission factors in the U.S., depending also on the average degree of fuel use in that region (coal, oil, natural gas, nuclear, renewable). These factors are updated often, even annually, enabling them to be up to date. Other excellent sources of emission factors are The Climate Registry and the USEPA. Most of these emission factors overlap, but there may be minor differences.

It should be noted that throughout this course, reference is made to "estimating" GHG emissions, rather than "calculating" GHG emissions. This is because emission factors, while useful, may not be accurate for the type of equipment used at your particular facility or your particular source of electricity (differs from average national or state factors). Certainly, if your company has more accurate, site-specific emission factors, it should use them over general published factors. However, it should be noted that by not measuring GHGs directly (and even measurement has its inaccuracies), strong accuracy is not likely to be achieved.

Electricity, fuel usage, mileage, or other parameters multiplied by the appropriate GHG emission factor will determine GHG emissions. Because climate change programs have originated and were greatly developed in Europe and Japan, most GHG emissions are expressed in metric units, such as kilograms (kg) or metric tons (tonnes). Therefore, many programs in the U.S. require expression of GHG emissions and reductions in metric units, as well.

While $CO_2$ is the most common GHG, there are a total of six recognized GHGs, including $CH_4$, $N_2O$, HFCs, CFCs, and $SF_6$. Each compound or compound within a class has a different "global warming potential". According to the UN's Intergovernmental Panel on Climate Change (IPCC) report in 2007, the global warming potentials (GWP) for the common GHGs were shown above in Table 1. For conformance, some registries require calculation of GHG emissions using older versions of the GWP.

These factors should be used in GHG emission calculations. For example, reducing 1 tonne of $CH_4$ is equivalent to reducing 25 tonnes of $CO_2$. In fact, reducing 1 pound of $SF_6$ is equivalent to reducing 11.4 short tons of $CO_2$.

Therefore, when compiling an inventory of total company GHG emissions, one need to take global warming potentials into consideration, developing an emission rate called $CO_2$ equivalents or "$CO_2e$". For example, a company determines that its Scope 1 emissions for a given year equals 45,000 tonnes $CO_2$, 945 tonnes $CH_4$, and 20 tonnes of $N_2O$, based on emission factors for their boilers for their particular fuels that cover these three GHGs. Its total Scope 1 GHG emissions would be (45,000) + (945 x 25) + (20 x 298) = 74,585 tonnes $CO_2e$. Although the mass rates of $CH_4$ and $N_2O$ are much lower than $CO_2$, the emissions expressed as GHGs and given their global warming potentials are nearly as high as $CO_2$'s.

In addition, from a strategic point of view, each GHG's global warming potential introduces a different approach for emission reductions. It may be more cost effective for a company to reduce 1 tonne of $CH_4$ from its operations (for example, permanently repairing leaks of natural or landfill gas) than 25 tonnes of $CO_2$ (for example, from a boiler upgrade) or 1 pound of $SF_6$ compared to 11.4 short tons of $CO_2$. This can give the company more options to reduce GHG emissions in a cost-effective manner.

While GHG emissions are commonly reported in a mass unit per year as discussed above, this is limiting as it is difficult to compare facilities, divisions, or processes. GHG emissions can also be useful if normalized to an appropriate activity, such as kg $CO_2$e emitted per tonne of chemical produced, kg per sq.m. of office space, kg per $ revenue, or kg per KWh electricity produced or used. This allows easier facility to facility comparisons, and allows the company to better strategize on areas for effective potential efficiency improvements. Such a calculation, therefore, is dependent on selecting the appropriate activity to normalize to and on obtaining the appropriate quality data covering the same period as GHG emissions. For example, a chemical manufacturer of various cosmetics and hair sprays recently performed their GHG emissions inventory based on GHG emissions per ton of base gel product manufactured. The base gel is then converted to their specific products. They found one plant had a significantly higher normalized GHG emission factor than their other plants. While other business reasons were also involved, this company chose that plant to shut down and replace with a new, modernized, "greener" plant.

## CARBON FOOTPRINTING

Similar to a baseline GHG emissions inventory described above, there is something called a "carbon footprint". This is really a misnomer as the user is not computing emissions of an entity called "carbon." Carbon, as better understood by the public, is a short euphemism for GHGs. The "footprint" represents the "permanent" mark left by the company (in terms of GHG emissions) from activities related to its being and its products. What differentiates a baseline GHG emissions inventory from a carbon footprint is that the former generally only includes activities that the company has direct control over. A carbon footprint also includes emissions from activities related to its products that the company does not have direct control.

The baseline GHG emissions inventory discussed above focuses on activities that the company controls, such as manufacturing and transportation of product to warehouses or retail stores. However, the life cycle of a product that a company manufactures includes many additional steps from which GHGs may be emitted. The carbon footprint represents a calculation of these other sources of GHG emissions. It represents additional opportunities for more cost effective GHG emission reductions. A life cycle analysis or assessment (LCA) is an estimation of GHG emissions from each step in the life cycle of a product. The steps of a product life cycle include:

- **Creation of “capital goods”.** The building of the factories, roads, equipment, and remaining infrastructure that allows manufacturing of the product is an activity that could potentially result in GHG emissions. The contribution of this area is generally minor, given the fact that the plant and roads, once built, will exist to help create products for many decades. In addition, such capital goods are commonly used for other products as well. Therefore, normalized to the amount of product manufactured, GHG emissions from this stage of the life cycle are generally minor. However, in some cases, it may be significant, particularly in companies that must invest heavily in R&D (and R&D buildings) before the product is developed.

- **Development of raw materials.** While the company manufacturing the product assembles, owns, and sells the product, manufacturing depends on the gathering of the proper raw materials. Raw materials, such as metals and plastics for certain machinery or equipment, chemicals for other chemicals or pharmaceuticals, or food products to make other food products, are mined, processed, or manufactured by other companies (or farmers) for the company making the product. While there is usually a contract between parties that lists certain quality conditions of the material, how the raw material is treated and its GHG emissions are not included as conditions. The farmer/manufacturer processes the material as it wishes, with varying quantities of GHG emissions resulting. GHG emission rates from transportation of raw material to the manufacturing plant need to be calculated as well. Raw materials from “renewable” sources such as wood or other “bio” sources which is presumed to be replenished and replanted, is (in many registries) considered as zero GHG emissions, as a new tree or plant acting as a “sink” for $CO_2$ will grow and develop for every one removed.

- **Manufacturing and production.** As discussed earlier in the baseline GHG emissions inventory, this is the combustion of fuel in boilers, the purchasing of electricity and steam, the emission of GHGs in the manufacturing and packaging processes, and the use of mobile equipment at the plant necessary to produce the product and provide comfort to workers.

- **Transportation.** Also as discussed earlier, the transportation of final product in trucks, trains, barges, or airlines to warehouses and/or retail stores results in fuel burning, resulting in GHG emissions. The quantity of GHG emissions from transportation depends on the source’s fuel efficiency and the routes between the manufacturing plants and warehouse and retail locations.

- **Sales and Consumer End Use.** Once the product is transported, it stays in the retail store and is used by the consumer, potentially causing GHG emissions. The product will be used by some end consumer, potentially using electricity or causing a fuel to be combusted. Based on the nature of the product and its properties, more or fewer GHGs may be emitted.

- **Waste Management and End of Life.** After the product is used, it must be disposed of. It may need to be transported; thereby, causing GHG emissions. If it is disposed in a landfill, it may result in methane ($CH_4$) emissions; a potent GHG from landfill gas. On the other hand, the product may be recyclable. The act of recycling may cause GHG emissions, but in many cases, this is much lower than the GHGs emitted when manufacturing a new "replacement" product.

A carbon footprint is a collection of GHG emission rates (or normalized emission rates as described above) for GHGs from these categories. They are often graphically shown as a bar graph, with a bar for the latter 5 categories (capital goods being so low that it is often not included) for comparison purposes. In some graphical showings of carbon footprints, the user places emissions of the 5 categories in different colors within the shape of a foot, with the width representing the quantity of emissions of each category or among the five toes of a foot.


Carbon footprints can provide useful information for companies. For example, a manufacturer of common kitchen appliances recently published the results of its carbon footprint. According to their numbers, well under 5% of total GHG emissions from the life cycle of their appliances came from their assembly and manufacturing; the items that it controls. About 95% of total GHG emissions occurred in one stage: consumer end use. In other words, GHG emissions from electricity was needed (from a power plant some distance away from the user) to operate the appliances, particularly refrigerators (24 hours per day) for many years. This result indicated to the manufacturer that there was no need to perform an overhaul of its manufacturing process to reduce GHG emissions because it accounted for less than 5% of the total. Instead, the manufacturer dedicated its resources to produce more efficient appliances (by using less electricity or hot water) as the best "bang for the buck" to reduce GHG emissions during the life cycle of their products.

Another interesting example is of a yogurt manufacturer which performed a carbon footprint. Its results claimed that about 70% of GHG emissions of yogurt derive from one category: raw materials; specifically the manufacturing of the milk needed to make yogurt. More specifically, most of these GHG emissions are comprised of methane from the cows, although some derive from $CO_2$ indirectly emitted during the pasteurization of the milk; an energy-intensive activity. As a result of this carbon footprint, the yogurt manufacturer began to include in their contracts with dairy farmers requirements to feed their cows a certain mixture of grains to minimize flatulence and energy minimizing standards.

Together, the carbon footprint is the result of a life cycle assessment (LCA). ISO standards 14040 and 14044 are the global standards to perform an LCA. Details of how specifically to perform an LCA are beyond the scope of this course. However, it is critical to perform a strategic assessment of all portions of product life and to collect quality, thorough, accurate data.

LCAs are of growing significance these days. In recent years, major retailers (such as Wal-Mart and Tesco) are requesting LCA information for a growing number of products; in particular the GHG emissions per unit (for example: per lb or liter or MW used of the item) covering the product life cycle from gathering and processing the necessary raw materials to delivery to the store. The purpose of this exercise from the retailer's point of view is for consumers to have appropriate information for comparative purposes, as there are a growing number of consumers who make choices based on environmental factors. The goal of Tesco, the UK retail giant, is to eventually have "carbon labels" for every product, perhaps similar to current nutritional labels on food products. Also, information from an LCA can allow a company to prioritize what areas to focus its resources to reduce GHG emissions.

An LCA may also be useful in one other context. An LCA may be used to study different fates of use of a product. If a precursor is removed from the preparation of a certain product and undergoes a different series of steps to form a different product, an LCA can compare the different GHG emission fates of the originating compound(s). The LCA can estimate GHG emissions from the production, transportation, use, and waste management to form and use the "traditional" product, as well as, from the production, transportation, use, and waste management to form and use the "alternative" product. If the alternative product results in lower GHG emissions, then this could be a major selling point for the alternative product or process. Several entrepreneurs of new products or new applications of existing products can gain a competitive sales advantage if they can prove that their new application results in fewer GHG emissions. A recent entrepreneur of a methodology to convert animal wastes into a burnable fuel is in the process of calculating GHG emissions avoided by farmers, by not having lagoons on their properties and by not combusting fossil fuels. The entrepreneur hopes that the potential for buyers to earn sellable carbon credits based on these GHG emission reductions (shutting down the lagoons) will help boost sales.

## KEEPING TRACK OF GHG EMISSIONS; DATA MANAGEMENT

After the baseline GHG emissions inventory and/or carbon footprint is complete, the company will study the results to determine potentially effective GHG emission reduction strategies. It is critical to keep a running total of GHG emissions for all of the plants and operations and to determine how effective each utilized GHG emission reduction strategy was and by how much it reduced total emissions. In addition, it is important to manage change, such as new facilities, new products, new procedures, etc., which in turn, will cause changes in GHG emissions.

Therefore GHG data management and treatment are important issues. They must remain consistent from year to year, including the type and quality of data collected and inputted, as well as the adequacy of emission factors. If published emission factors change, it may be necessary to change previous GHG emission totals in the records.

For most initial GHG emission inventories, plant data is entered and calculations performed on an Excel spreadsheet. This usually suffices adequately. However, it is important for a company to ultimately invest in an effective GHG data management system for the long term. When data is collected over several years and accounting for changes and growth and new facilities and processes is necessitated, an Excel spreadsheet may become a liability. In addition, some companies keep track of GHG emission reductions in order to obtain sellable carbon credits, introducing another complication. Report writing to an agency may be a necessity, too, with certain requirements. Finally, with turnover in staff, consistency over time is a challenge. These factors point to the importance of developing a reliable GHG data management and emission calculation and reporting system.

Based on the growth of climate change programs worldwide in response to the Kyoto Protocol, a number of firms have developed software specific for GHG data management. It is advantageous for a company to research and invest in such software for a long-term climate change program to save time and money in terms of data management. Ideally, such software should be able to “communicate” with not only existing environmental software, but also with business software as well, as business parameters like carbon credits may be involved

Typically, a GHG software evaluation begins with a needs assessment. What are the unique needs that a company’s climate change program has that must be addressed by the software? (Some examples include the number of facilities, the quantity of data, the changeability of processes and data, or the need to compute reductions and potential credits). How can the software address company climate change goals? What are the company’s current environmental and business software systems? How does climate change data interact with or are components of these systems? Can new GHG software “communicate” with these existing systems? Can the climate change needs identified above be incorporated into existing company software?

A professional assessment and recommendations for software to manage GHG data and communicate to existing environmental and business software are critical. Three potential options to choose from in terms of cost and operational effectiveness include:

- modify existing software to meet future climate change needs;
- purchase an existing specific commercially-available GHG data management system with incorporation of changes to the code by the vendor to meet company-specific needs; or
- develop GHG management software from “scratch”.

Finally, the GHG software needs to have a reporting function, the ability to print out appropriate reports for a variety of internal and external purposes (such as reports for reporting GHG emissions to the USEPA as required in 40CFR Part 98 and internal reports on progress in meeting internal energy and/or GHG emission reduction goals) and the ability to keep track of potential carbon credits earned. The software should be programmed to provide this wide variety of reports for short or annual time periods.