6 Identifying and Calculating GHG Emissions

Once the inventory boundary has been established, companies generally calculate GHG emissions using the following steps:

1. Identify GHG emissions sources
2. Select a GHG emissions calculation approach
3. Collect activity data and choose emission factors
4. Apply calculation tools
5. Roll-up GHG emissions data to corporate level.

This chapter describes these steps and the calculation tools developed by the GHG Protocol. The calculation tools are available on the GHG Protocol Initiative website at www.ghgprotocol.org.

To create an accurate account of their emissions, companies have found it useful to divide overall emissions into specific categories. This allows a company to use specifically developed methodologies to accurately calculate the emissions from each sector and source category.

Identify GHG emissions sources

The first of the five steps in identifying and calculating a company's emissions as outlined in Figure 9 is to categorize the GHG sources within that company's boundaries. GHG emissions typically occur from the following source categories:

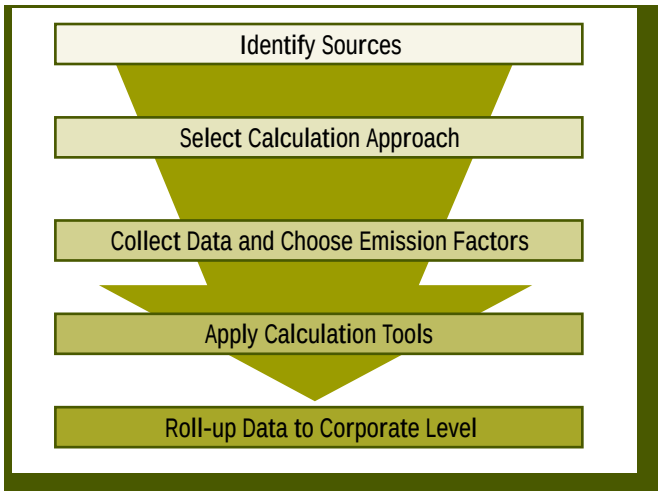
- **Stationary combustion:** combustion of fuels in stationary equipment such as boilers, furnaces, burners, turbines, heaters, incinerators, engines, flares, etc.
- **Mobile combustion:** combustion of fuels in transportation devices such as automobiles, trucks, buses, trains, airplanes, boats, ships, barges, vessels, etc.
- **Process emissions:** emissions from physical or chemical processes such as CO_2 from the calcination step in cement manufacturing, CO_2 from catalytic cracking in petrochemical processing, PFC emissions from aluminum smelting, etc.
- **Fugitive emissions:** intentional and unintentional releases such as equipment leaks from joints, seals, packing, gaskets, as well as fugitive emissions from coal piles, wastewater treatment, pits, cooling towers, gas processing facilities, etc.

Every business has processes, products, or services that generate direct and/or indirect emissions from one or more of the above broad source categories. The *GHG Protocol* calculation tools are organized based on these categories. Appendix D provides an overview of direct and indirect GHG emission sources organized by scopes and industry sectors that may be used as an initial guide to identify major GHG emission sources.

IDENTIFY SCOPE 1 EMISSIONS

As a first step, a company should undertake an exercise to identify its direct emission sources in each of the four source categories listed above. Process emissions are usually only relevant to certain industry sectors like oil and gas, aluminum, cement, etc. Manufacturing companies that generate process emissions and own or control a power production facility will likely have direct emissions from all the main source categories. Office-based organizations may not have any direct GHG emissions except in cases where they own or operate a vehicle, combustion device, or refrigeration and air-conditioning equipment. Often companies are surprised to realize that significant emissions come from sources that are not initially obvious (see United Technologies case study).

FIGURE 9.
Steps in identifying and calculating GHG emissions



IDENTIFY SCOPE 2 EMISSIONS

The next step is to identify indirect emission sources from the consumption of purchased electricity, heat, or steam. Almost all businesses generate indirect emissions due to the purchase of electricity for use in their processes or services.

IDENTIFY SCOPE 3 EMISSIONS

This optional step involves identification of other indirect emissions from a company's upstream and downstream activities as well as emissions associated with outsourced/contract manufacturing, leases, or franchises not included in scope 1 or scope 2.

The inclusion of scope 3 emissions allows businesses to expand their inventory boundary along their value chain and to identify all relevant GHG emissions. This provides a broad overview of various business linkages and possible opportunities for significant GHG emission reductions that may exist upstream or downstream of a company's immediate operations (see chapter 4 for an overview of activities that can generate GHG emissions along a company's value chain).

Select a calculation approach

Direct measurement of GHG emissions by monitoring concentration and flow rate is not common. More often, emissions may be calculated based on a mass balance or stoichiometric basis specific to a facility or process. However, the most common approach for calculating GHG emissions is through the application of documented emission factors. These factors are calculated ratios relating GHG emissions to a proxy measure of activity at an emissions source. The IPCC guidelines (IPCC, 1996) refer to a hierarchy of calculation approaches and techniques ranging from the application of generic emission factors to direct monitoring.

In many cases, particularly when direct monitoring is either unavailable or prohibitively expensive, accurate emission data can be calculated from fuel use data. Even small users usually know both the amount of fuel consumed and have access to data on the carbon content of the fuel through default carbon content coefficients or through more accurate periodic fuel sampling. Companies should use the most accurate calculation approach available to them and that is appropriate for their reporting context.

United Technologies Corporation: More than meets the eye

In 1996, United Technologies Corporation (UTC), a global aerospace and building systems technology corporation, appointed a team to set boundaries for the company's new Natural Resource Conservation, Energy and Water Use Reporting Program. The team focused on what sources of energy should be included in the program's annual report of energy consumption. The team decided jet fuel needed to be reported in the annual report; jet fuel was used by a number of UTC divisions for engine and flight hardware testing and for test firing. Although the amount of jet fuel used in any given year was subject to wide variation due to changing test schedules, the total amount consumed in an average year was believed to be large and potentially small enough to be specifically excluded. However, jet fuel consumption reports proved that initial belief incorrect. Jet fuel has accounted for between 9 and 13 percent of the corporation's total annual use of energy since the program commenced. Had UTC not included the use of jet fuel in annual data collection efforts, a significant emissions source would have been overlooked.

Collect activity data and choose emission factors

For most small to medium-sized companies and for many larger companies, scope 1 GHG emissions will be calculated based on the purchased quantities of commercial fuels (such as natural gas and heating oil) using published emission factors. Scope 2 GHG emissions will primarily be calculated from metered electricity consumption and supplier-specific, local grid, or other published emission factors. Scope 3 GHG emissions will primarily be calculated from activity data such as fuel use or passenger miles and published or third-party emission factors. In most cases, if source- or facility-specific emission factors are available, they are preferable to more generic or general emission factors.

Industrial companies may be faced with a wider range of approaches and methodologies. They should seek guidance from the sector-specific guidelines on the GHG Protocol website (if available) or from their industry associations (e.g., International Aluminum Institute, International Iron and Steel Institute, American Petroleum Institute, WBCSD Sustainable Cement Initiative, International Petroleum Industry Environmental Conservation Association).

Apply calculation tools

This section provides an overview of the GHG calculation tools and guidance available on the GHG Protocol Initiative website (www.ghgprotocol.org). Use of these tools is encouraged as they have been peer reviewed by experts and industry leaders, are regularly updated, and are believed to be the best available. The tools, however, are optional. Companies may substitute their own GHG calculation methods, provided they are more accurate than or are at least consistent with the *GHG Protocol Corporate Standards* approaches.

There are two main categories of calculation tools:

- **Cross-sector tools** that can be applied to different sectors. These include stationary combustion, mobile combustion, HFC use in refrigeration and air conditioning, and measurement and estimation uncertainty.
- **Sector-specific tools** that are designed to calculate emissions in specific sectors such as aluminum, iron and steel, cement, oil and gas, pulp and paper, office-based organizations.

Most companies will need to use more than one calculation tool to cover all their GHG emission sources. For example, to calculate GHG emissions from an aluminum production facility, the company would use the calculation tools for aluminum production, stationary combustion (for any consumption of purchased electricity, generation of energy on-site, etc), mobile combustion (for transportation of materials and products by train, vehicles employed on-site, employee business travel, etc), and HFC use (for refrigeration, etc). See Table 3 for the full list of tools.

STRUCTURE OF GHG PROTOCOL CALCULATION TOOLS

Each of the cross-sector and sector-specific calculation tools on the website share a common format and include step-by-step guidance on measuring and calculating emissions data. Each tool consists of a guidance section and automated worksheets with explanations on how to use them.

The guidance for each calculation tool includes the following sections:

- **Overview:** provides an overview of the purpose and content of the tool, the calculation method used in the tool, and a process description
- **Choosing activity data and emission factors:** provides sector-specific good practice guidance and references for default emission factors
- **Calculation methods:** describes different calculation methods depending on the availability of site-specific activity data and emission factors
- **Quality control:** provides good practice guidance
- **Internal reporting and documentation:** provides guidance on internal documentation to support emissions calculations.

ChevronTexaco: The SANGEA™ accounting and reporting system

ChevronTexaco, a global energy company, has developed and implemented energy utilization and GHG estimation and reporting software consistent with the *GHG Protocol Corporate Standard*. This software is available free of charge and makes it easier, more accurate, and less costly to institute a corporate-wide GHG accounting and reporting system in the oil and gas sector. Called the SANGEA™ Energy and Greenhouse Gas Emissions Estimating System, it is currently in use at all ChevronTexaco facilities worldwide, comprising more than 70 reporting entities.

The system is an auditable, Excel-and-Visual-Basic-based tool for estimating GHG emissions and energy utilization. It streamlines corporate-level data consolidation by allowing the inventory coordinator at each facility to configure a spreadsheet, enter monthly data, and send quarterly reports to a centralized database.

In practice, the SANGEA™ system employs a variety of strategies to ensure consistent calculation methods and ease company-wide standardization:

- Spreadsheet configuration and material input information for specific facilities can be carried over from year to year. Inventory specialists can easily modify configurations as a facility changes (due to new construction, retirement of units, etc.).
- Updates are efficient. Methodologies for estimating emissions, emission factors, and calculation equations are stored centrally in the software, easing updates when methodologies or default factors change. Updates to this central reference are automatically applied to the existing configuration and input data. Updates will mirror the timing and content of updates to the American Petroleum Institute Compendium of GHG emission estimating methodologies.
- The system is auditable. The software requires detailed audit trail information on data inputs and system users. There is documented accountability of who made any change to the system.
- Using one system saves money. Significant cost savings are achieved by using the same system in all facilities, as compared to conventional, disparate systems.

ChevronTexaco's one-off investment in developing the SANGEA™ system has already shown results: A rough cost estimate for ChevronTexaco's Richmond, California, refinery indicates savings of more than 70 percent over a five-year period compared with the conventional approaches based on locally developed reporting systems. SANGEA™ is expected to reduce the long term expenses of maintaining a legacy system and hiring independent consultants. Employing a combination of the *GHG Protocol Corporate Standard*s and SANGEA™ calculation software to replace a diverse and confusing set of accounting and reporting templates yields significant efficiency and accuracy gains, and allows the company to more accurately manage GHG emissions and institute specific emissions improvements.

TABLE 3. Overview of GHG calculation tools available on the GHG Protocol website

	CALCULATION TOOLS	MAIN FEATURES
CROSS-SECTOR TOOLS	Stationary Combustion	• Calculates direct and indirect CO_2 emissions from fuel combustion in stationary equipment • Provides two options for allocating GHG emissions from a co-generation facility • Provides default fuel and national average electricity emission factors
	Mobile Combustion	• Calculates direct and indirect CO_2 emissions from fuel combustion in mobile sources • Provides calculations and emission factors for road, air, water, and rail transport
	HFC from Air Conditioning and Refrigeration Use	• Calculates direct HFC emissions during manufacture, use and disposal of refrigeration and air-conditioning equipment in commercial applications • Provides three calculation methodologies: a sales-based approach, a life cycle stage based approach, and an emission factor based approach
	Measurement and Estimation Uncertainty for GHG Emissions	• Introduces the fundamentals of uncertainty analysis and quantification • Calculates statistical parameter uncertainties due to random errors related to calculation of GHG emissions • Automates the aggregation steps involved in developing a basic uncertainty assessment for GHG inventory data
SECTOR-SPECIFIC TOOLS	Aluminum and other non-Ferrous Metals Production	• Calculates direct GHG emissions from aluminum production (CO_2 from anode oxidation, PFC emissions from the "anode effect," and SF_6 used in non-ferrous metals production as a cover gas)
	Iron and Steel	• Calculates direct GHG emissions (CO_2) from oxidation of the reducing agent, from the calcination of the flux used in steel production, and from the removal of carbon from the iron ore and scrap steel used
	Nitric Acid Manufacture	• Calculates direct GHG emissions (N_2O) from the production of nitric acid
	Ammonia Manufacture	• Calculates direct GHG emissions (CO_2) from ammonia production. This is for the removal of carbon from the feedstock stream only; combustion emissions are calculated with the stationary combustion module
	Adipic Acid Manufacture	• Calculates direct GHG emissions (N_2O) from adipic acid production
	Cement	• Calculates direct CO_2 emissions from the calcination process in cement manufacturing (WBCSD tool also calculates combustion emissions) • Provides two calculation methodologies: the cement-based approach and the clinker-based approach
	Lime	• Calculates direct GHG emissions from lime manufacturing (CO_2 from the calcination process)
	HFC-23 from HCFC-22 Production	• Calculates direct HFC-23 emissions from production of HCFC-22
	Pulp and Paper	• Calculates direct CO_2, CH_4, and N_2O emissions from production of pulp and paper. This includes calculation of direct and indirect CO_2 emissions from combustion of fossil fuels, bio-fuels, and waste products in stationary equipment
	Semi-Conductor Wafer Production	• Calculates PFC emission from the production of semi-conductor wafers
	Guide for Small Office-Based Organizations	• Calculates direct CO_2 emissions from fuel use, indirect CO_2 emissions from electricity consumption, and other indirect CO_2 emissions from business travel and commuting

In the automated worksheet section, it is only necessary to insert activity data into the worksheets and to select an appropriate emission factor or factors. Default emission factors are provided for the sectors covered, but it is also possible to insert customized emission factors that are more representative of the reporting company's operations. The emissions of each GHG (CO_2, CH_4, N_2O, etc.) are calculated separately and then converted to CO_2 equivalents on the basis of their global warming potential.

Some tools, such as the iron and steel sector tool and the HFC cross-sector tool, take a tiered approach, offering a choice between a simple and a more advanced calculation methodology. The more advanced methods are expected to produce more accurate emissions estimates but usually require collection of more detailed data and a more thorough understanding of a company's technologies.

Roll-up GHG emissions data to corporate level

To report a corporation's total GHG emissions, companies will usually need to gather and summarize data from multiple facilities, possibly in different countries and business divisions. It is important to plan this process carefully to minimize the reporting burden, reduce the risk of errors that might occur while compiling data, and ensure that all facilities are collecting information on an approved, consistent basis. Ideally, corporations will integrate GHG reporting with their existing reporting tools and processes, and take advantage of any relevant data already collected and reported by facilities to division or corporate offices, regulators or other stakeholders.

The tools and processes chosen to report data will depend upon the information and communication infrastructure already in place (i.e., how easy is it to include new data categories in corporate databases). It will also depend upon the amount of detail that corporate headquarters wishes to be reported from facilities. Data collection and management tools could include:

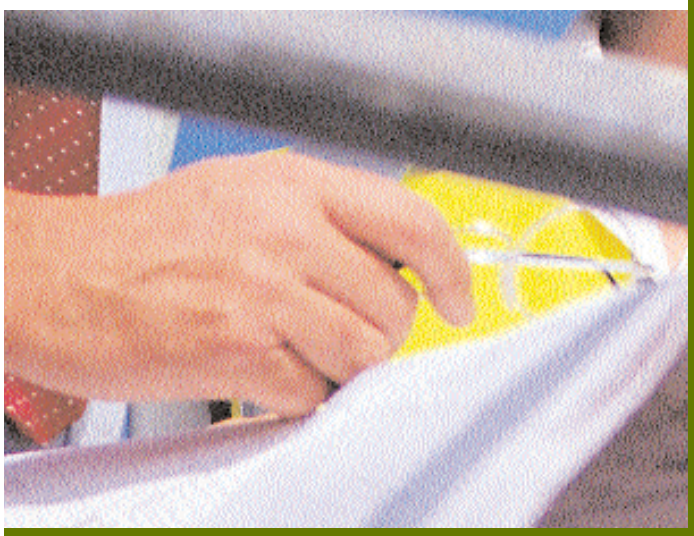
- Secure databases available over the company intranet or internet, for direct data entry by facilities
- Spreadsheet templates filled out and e-mailed to a corporate or division office, where data is processed further
- Paper reporting forms faxed to a corporate or division office where data is re-entered in a corporate database. However, this method may increase the likelihood of errors if there are not sufficient checks in place to ensure the accurate transfer of the data.

BP: A standardized system for internal reporting of GHGs

BP, a global energy company, has been collecting GHG data from the different parts of its operations since 1997 and has consolidated its internal reporting processes into one central database system. The responsibility for reporting environmental emissions lies with about 320 individual BP facilities and business departments, which are termed "reporting units." All reporting units have to complete a standard Excel pro-forma spreadsheet every quarter, stating actual emissions for the preceding three months and updates to forecasts for the current year and the next two years. In addition, reporting units are asked to account for all significant variances, including sustainable reductions. The reporting units all use the same BP GHG Reporting Guidelines "Protocol" (BP, 2000) for quantifying their emissions of carbon dioxide and methane.

All pro-forma spreadsheets are e-mailed automatically by the central database to the reporting units, and the completed e-mail returns are uploaded into the database by a corporate team, who check the quality of the incoming data. The data are then compiled, by the end of the month following each quarter end, to provide the total emission inventory and forecasts for analysis against BP's GHG target. Finally, the inventory is reviewed by a team of independent external auditors to provide assurance on the quality and accuracy of the data.

For internal reporting up to the corporate level, it is recommended that standardized reporting formats be used to ensure that data received from different business units and facilities is comparable, and that internal reporting rules are observed (see BP case study). Standardized formats can significantly reduce the risk of errors.



Approaches for rolling up GHG emissions data to corporate level

There are two basic approaches for gathering data on GHG emissions from a corporation's facilities (Figure 10):

- **Centralized:** individual facilities report activity/fuel use data (such as quantity of fuel used) to the corporate level, where GHG emissions are calculated.
- **Decentralized:** individual facilities collect activity/fuel use data, directly calculate their GHG emissions using approved methods, and report this data to the corporate level.

FIGURE 10. Approaches to gathering data

	SITE LEVEL	CORPORATE LEVEL
CENTRALIZED	Activity data →	Sites report activity data (GHG emissions calculated at corporate level: activity data x emissions factor = GHG emissions)
DECENTRALIZED	Activity data x emission factor = GHG emissions →	Sites report GHG emissions

The difference between these two approaches is in where the emissions calculations occur (i.e., where activity data is multiplied by the appropriate emission factors) and in what type of quality management procedures must be put in place at each level of the corporation. Facility-level staff is generally responsible for initial data collection under both approaches.

Under both approaches, staff at corporate and lower levels of consolidation should take care to identify and exclude any scope 2 or 3 emissions that are also accounted for as scope 1 emissions by other facilities, business units, or companies included in the emissions inventory consolidation.

CENTRALIZED APPROACH: INDIVIDUAL FACILITIES REPORT ACTIVITY/FUEL USE DATA

This approach may be particularly suitable for office-based organizations. Requesting that facilities report their activity/fuel use data may be the preferred option if:

- The staff at the corporate or division level can calculate emissions data in a straightforward manner on the basis of activity/fuel use data; and
- Emissions calculations are standard across a number of facilities.

DECENTRALIZED APPROACH: INDIVIDUAL FACILITIES CALCULATE GHG EMISSIONS DATA

Asking facilities to calculate GHG emissions themselves will help to increase their awareness and understanding of the issue. However, it may also lead to resistance, increased training needs, an increase in calculation errors, and a greater need for auditing of calculations. Requesting that facilities calculate GHG emissions themselves may be the preferred option if:

- GHG emission calculations require detailed knowledge of the kind of equipment being used at facilities;
- GHG emission calculation methods vary across a number of facilities;
- Process emissions (in contrast to emissions from burning fossil fuels) make up an important share of total GHG emissions;
- Resources are available to train facility staff to conduct these calculations and to audit them;
- A user-friendly tool is available to simplify the calculation and reporting task for facility-level staff; or
- Local regulations require reporting of GHG emissions at a facility level.

The choice of collection approach depends on the needs and characteristics of the reporting company. For example, United Technologies Corporation uses the centralized approach, leaving the choice of emission factors and calculations to corporate staff, while BP uses the decentralized approach and follows up with audits to ensure calculations are correct, documented, and follow approved methods. To maximize accuracy and minimize reporting burdens, some companies use a combination of the two approaches. Complex facilities with process emissions calculate their emissions at the facility level, while facilities with uniform emissions from standard sources only report fuel use, electricity consumption, and travel activity. The corporate database or reporting tool then calculates total GHG emissions for each of these standard activities.

The two approaches are not mutually exclusive and should produce the same result. Thus companies desiring a consistency check on facility-level calculations can follow both approaches and compare the results. Even when facilities calculate their own GHG emissions, corporate staff may still wish to gather activity/fuel use data to double-check calculations and explore opportunities for emissions reductions. These

data should be available and transparent to staff at all corporate levels. Corporate staff should also verify that facility-reported data are based on well defined, consistent, and approved inventory boundaries, reporting periods, calculation methodologies, etc.

Common guidance on reporting to corporate level

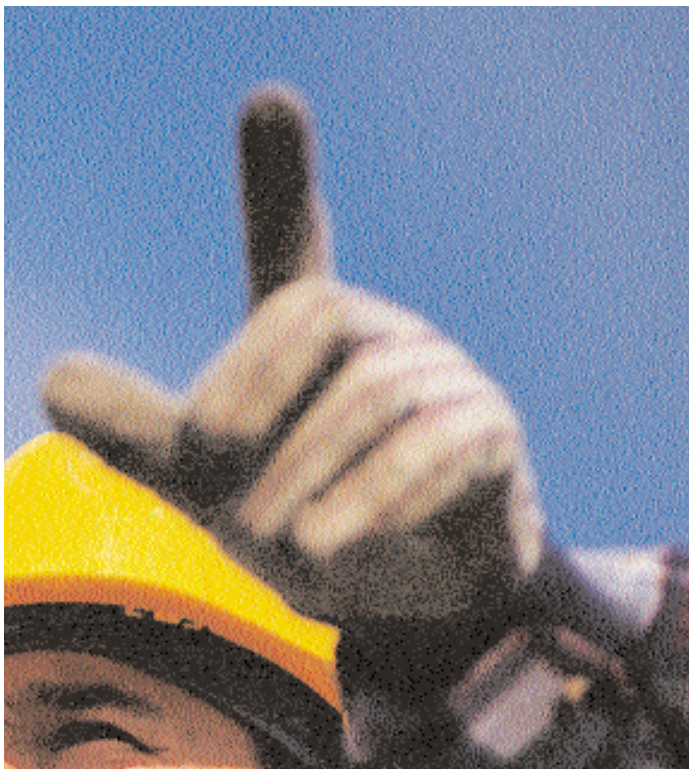
Reports from facility level to corporate or division offices should include all relevant information as specified in chapter 9. Some reporting categories are common to both the centralized and decentralized approaches and should be reported by facilities to their corporate offices. These include:

- A brief description of the emission sources
- A list and justification of specific exclusion or inclusion of sources
- Comparative information from previous years
- The reporting period covered
- Any trends evident in the data
- Progress towards any business targets
- A discussion of uncertainties in activity/fuel use or emissions data reported, their likely cause, and recommendations for how data can be improved
- A description of events and changes that have an impact on reported data (acquisitions, divestitures, closures, technology upgrades, changes of reporting boundaries or calculation methodologies applied, etc.).

REPORTING FOR THE CENTRALIZED APPROACH

In addition to the activity/fuel use data and aforementioned common categories of reporting data, facilities following the centralized approach by reporting activity/fuel use data to the corporate level should also report the following:

- Activity data for freight and passenger transport activities (e.g., freight transport in tonne-kilometers)
- Activity data for process emissions (e.g., tonnes of fertilizer produced, tonnes of waste in landfills)
- Clear records of any calculations undertaken to derive activity/fuel use data
- Local emission factors necessary to translate fuel use and/or electricity consumption into CO_2 emissions.



REPORTING FOR THE DECENTRALIZED APPROACH

In addition to the GHG emissions data and aforementioned common categories of reporting data, individual facilities following the decentralized approach by reporting calculated GHG emissions to the corporate level should also report the following:

- A description of GHG calculation methodologies and any changes made to those methodologies relative to previous reporting periods
- Ratio indicators (see chapter 9)
- Details on any data references used for the calculations, in particular information on emission factors used.

Clear records of calculations undertaken to derive emissions data should be kept for any future internal or external verification.