CHAPTER 2

APPROACHES TO DATA COLLECTION

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Users are expected to go to Mapping Tables in Annex 1, before reading this chapter. This is required to correctly understand both the refinements made and how the elements in this chapter relate to the corresponding chapter in the 2006 IPCC Guidelines.

2.1 INTRODUCTION

Data collection is a key part of the national inventory arrangements a country puts into place to regularly estimate and report greenhouse gas emissions and removals. In establishing routine, formalised, data collection use should be made of existing statistical organisations and other official data wherever possible. *Good practice* data collection is adapted to national circumstances and reviewed periodically.

Data collection procedures include finding and processing existing data, (i.e., data that are compiled and stored for other statistical or administrative uses than the inventory), as well as generating new data by surveys or measurement campaigns. During the data collection for the greenhouse gas inventory, interactions between the inventory compilers and stakeholders will take place. These interactions may be the most time-consuming part of the emission inventory compilation process even when much of the data may be freely available via the internet. A network of data providers will need to provide information on an annual basis. This network may include national statistical agencies, ministries, international organizations, academia, economic sectors such as industries, trade, transport, service sector, and others depending on national circumstances. Other activities related to data collection include maintaining data flows, improving estimates, generating estimates for new categories and/or replacing existing data sources when those currently used are no longer available.

This chapter presents the approaches to data collection that cover gathering of existing data and generating new data, for emission factors and direct measurement of emissions and activity data in Section 2.2. Section 2.3 covers the use of facility data in inventories. Data reporting and archiving are covered in Section 1.5 of Chapter 1 and Section 6.11 of Chapter 6 of the *2006 IPCC Guidelines*. Data archiving is vital to ensure that subsequent inventories can be compiled in a consistent and efficient manner. A good data archive also is an important contributor to the inventory transparency. Figure 2.0b outlines the steps in data collection in established emission inventories.

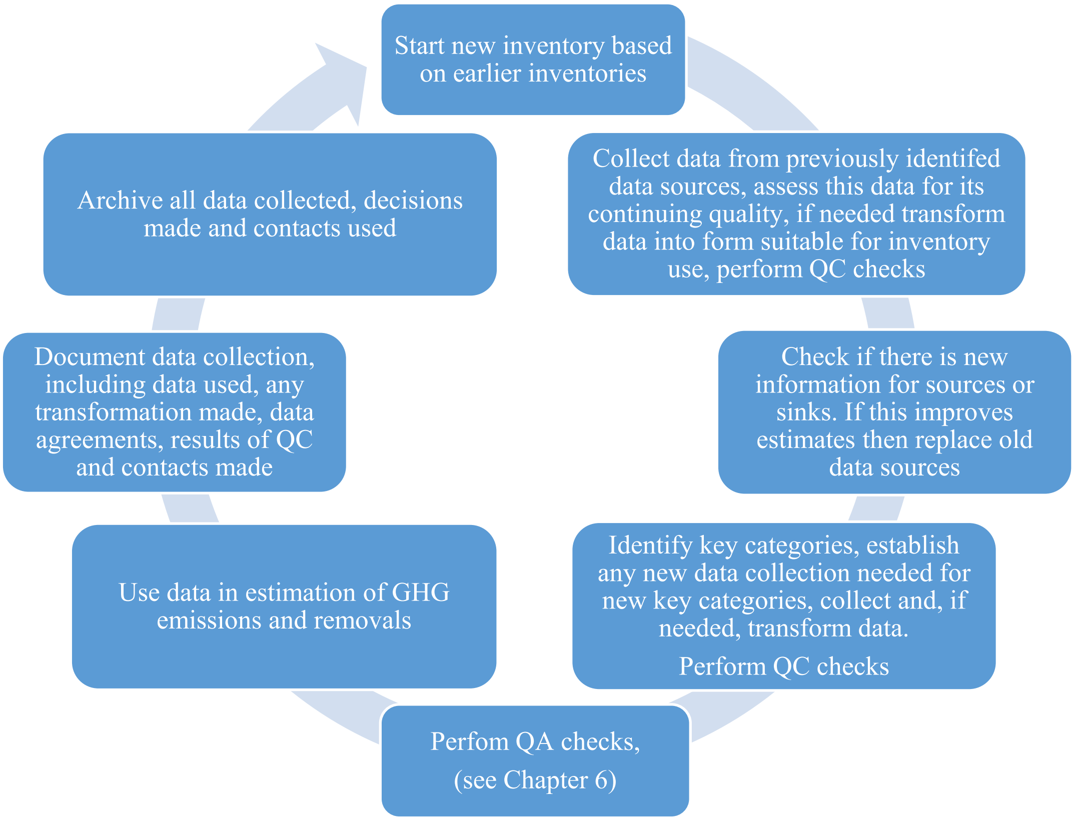
When starting the inventory compilation for the first time, it will be necessary to identify *key categories* which should[1] be estimated using higher tier methods. It is *good practice* to use at least Tier 1 method for non-key categories (see Volume 1, Chapter 4). In order to identify potential *key categories*, it may be best to make estimates with readily available information, without expending too much effort in collecting new information and then follow the guidance on methodological choice (Volume 1, Chapter 4) to identify potential *key categories*. Alternatively, expert judgement could be used initially to identify likely *key categories*: inventory compilers likely know, or can find out relatively easily, candidate categories such as major fossil fuel consumption, major agriculture activities, all types of forests and major industries. Resources can then be focused on improving data for categories identified as *key categories*.

Once an inventory has been established, adding new categories should be easier with the relationships and processes already established. However, compilers should always be prepared to consider replacing data sources with better ones (for example more reliable, accurate, affordable, accessible or timely) should they become available.

In established inventories, new sources of greenhouse gas emissions or sinks may be identified. In most cases generating new source data will be limited by the resources available and prioritisation will be needed, taking account of the results of key category analysis set out in Volume 1, Chapter 4, Methodological Choice and Identification of Key Categories. In these cases, it is *good practice* to make an initial estimate of the source and/or sink emissions or removals and compare this to the magnitude of *key categories* in order to assess and prioritize the effort required. Such initial estimates can be very rough and may be based on expert judgement as they are intended to guide resource use and not contribute to the final inventory totals. If a new source or sink is estimated to be on a scale similar to the *key categories* then it is *good practice* to use Tier 2 or 3 methods, and data collection should be planned accordingly.

[1] Section 4.1.2 of Volume 1, Chapter 4 provides guidance where lack of resources limits the ability of an inventory compiler to adopt a higher tier for all *key categories*. As a Tier 1 estimate is always possible, it will always be possible for an inventory compiler to produce a complete inventory.

Figure 2.0a (New) Steps in data collection



Note: This diagram outlines the steps in collecting and using data. In practice, some of the steps may be done in a different order or at different times for different sectors to suit national needs and circumstances. For example, documentation may be completed earlier than shown here.

The methodological principles of data collection that underpin *good practice* are the following:

- Identify, evaluate and document data sources.
- Use existing data from national statistical organizations and other official data collections where this is available and suitable for use in the emission inventory. Close working arrangements with existing systems will make best use of national expertise, minimize duplication, and increase efficiency.
- Focus on the collection of data needed to improve estimates of *key categories*.
- Collect data/information at a level of detail appropriate to the method used.
- Collect information about uncertainty which is an integral part of data collection for both emission factors and activity data (Chapter 3 discusses uncertainties).
- Establish agreements with data suppliers to support consistent and continuing information flows.
- Fully document all the data collection activities, decisions and data sources and archive this information.
- Establish a system for continuous improvement:
  - (i) data collection procedures that iteratively improve the quality of the inventory in line with the data quality objectives (e.g. transparency, consistency, comparability, completeness and accuracy);
  - (ii) review data collection activities and methodological needs on a regular basis, to guide progressive, and efficient, inventory improvement;
  - (iii) put in place data collection activities (resource prioritisation, planning, implementation, documentation etc.) that lead to continuous improvement of the datasets used in the inventory.
- Ensure consistency, completeness, comparability, accuracy, and transparency using guidance provided in Chapter 6, Quality assurance/Quality control (QA/QC) and Verification, of Volume 1.

This chapter provides general guidance for collecting existing national/international data and new data. The material is intended both for countries establishing a data collection strategy for the first time and for countries with established data collection procedures. It is applicable to emission factor, activity, and uncertainty data collection. It covers:

- developing a data collection strategy to meet data quality objectives regarding timelines, and also consistency, completeness, comparability, accuracy, and transparency using guidance provided in Chapter 6, QA/QC and Verification, of this volume;
- data acquisition activities including generating new source data, dealing with restricted data and confidentiality, and using expert judgement;
- turning the raw data into a form that is useful for the inventory.

Advice related to selecting emission factors focuses on understanding of measured data as well as where to find and when to use default factors. Guidance on activity data focuses on generating and using new census & survey data as well as providing guidance on the use of existing international data sets.

The chapter draws on information from a range of institutions and where possible additional documents have been identified and referenced so that users can find more detailed information. Sector specific data collection issues - like selecting the appropriate activity data for a particular category of emissions by sources and removals by sinks - are described in the sector specific Volumes 2-5.

2.2 COLLECTING DATA

This section provides general guidance for collecting existing data, generating new data, and adapting data for inventory use. The guidance is applicable to emission factors, activity and uncertainty data collection. It discusses separately specific issues relating to new data and existing data. Specific guidance for the collection/calculation of emission factors and the collection of activity and uncertainty data is provided subsequently. Throughout the data collection activities, the inventory compiler should maintain QA/QC records about the data collected according to the guidance provided in Chapter 6 of Volume 1. While collecting data it is *good practice* to be aware of future data collection needs.

In some cases, it may be possible to use emissions data directly from facilities, e.g. measured emissions such as the European Union Emissions Trading System (EU ETS) (see Section 2.3).

Following the *2006 IPCC Guidelines* and its *2019 Refinement*, it is possible to provide a Tier 1 estimate for every category. The sectoral volumes contain default Tier 1 emission factors and parameters that can be used. In the absence of available activity data, as a last resort, applying these guidelines will allow estimates to be made based on either surrogate information or expert judgement. It is *good practice* to use Tier 2 or 3 methods for *key categories*[2]. These data collection guidelines should be followed to collect the additional data needed for all tiers. The decision trees and sector-specific guidance for the respective category and additional *good practice* guidance in chapters in sectoral volumes will guide the choice of activity data needed.

When compiling an inventory or estimates for a specific source for the first time, it is *good practice* for inventory compilers to assess existing data and to acquire data in the following ways in order of priority (see Figure 2.0b):

1. Use existing data (Section 2.2.1):
    (i) national statistics;
    (ii) international statistics;
    (iii) other data sources including remote sensing, industrial associations and academia.
2. Engage in cooperation with data suppliers to provide tailored data sets from their information (Section 2.2.1).
3. Modify existing data sets to meet the inventory requirements (e.g. where data is not collected on a calendar year basis (e.g. financial year) convert to calendar year, adjust for different classifications of sources or fill gaps in territorial coverage) (Section 2.2.3).
4. Generate new data:

[2] Section 4.1.2 of Volume 1, Chapter 4 provides guidance where lack of resources limits the ability of an inventory compiler to adopt a higher tier for all *key categories*. As a Tier 1 estimate is always possible, it will always be possible for an inventory compiler to produce a complete inventory.

(i) make measurements (Sections 2.2.2 & 2.2.4);

(ii) use census and survey data (Section 2.2.5, Annex 2A.2);

(iii) coordinate with National Statistical Offices (NSO) to undertake new surveys targeting inventory relevant sectors.

5. Use surrogate data (Section 2.2.1: Surrogate Data).
6. If the above approaches are unsuccessful and as a last resort, it is *good practice* to use expert judgement (Section 2.2: Expert Judgement).

It is *good practice* to focus resources on categories that have been identified as *key categories*. Improving data for less important categories can be done in later years.

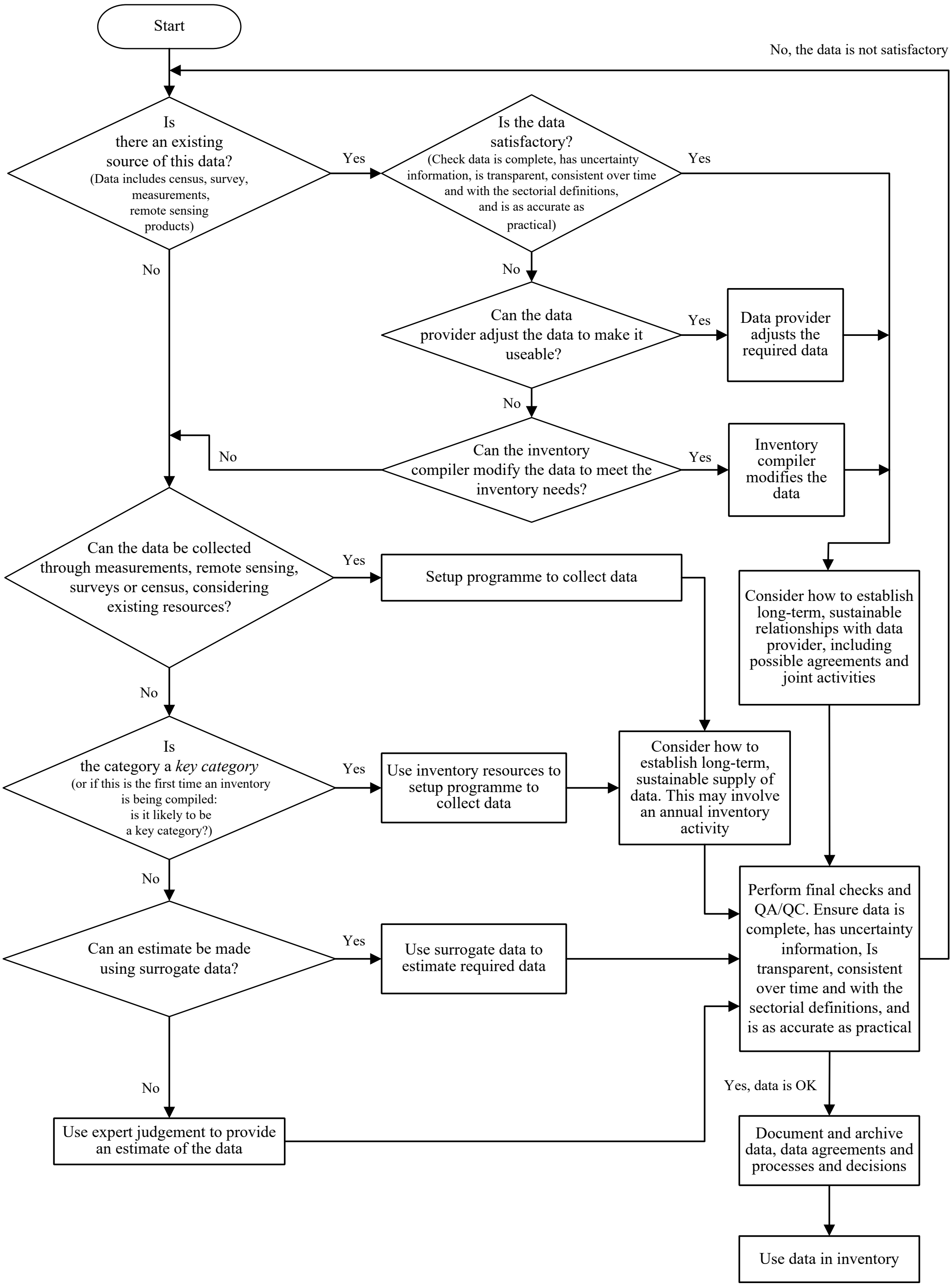
As data is collected, it is *good practice* for it to be checked considering the following points:

- Is it complete? Does it cover the entire territorial area of the inventory and/or the entire population of sources within the source category? Does the data represent collection for a complete calendar year?
- Does the data have associated measurement uncertainty information? (The uncertainty information should include the uncertainty range expressed in terms of 2.5 and 97.5% percentiles and may include information on the shape of the probability distribution function).
- What assumptions underlie the data? (E.g. is a survey representative? Is a census complete?).
- What measurement methods are used? Are they reliable?
- Are time series consistent? Does it include a complete time series?
- Has the collected data already undergone specific QA/QC procedures? Are these procedures documented?

A feedback mechanism, to provide comments/questions from the compiler to the data provider, should be formalized in any agreement to data supply. If problems are identified in the data, the inventory compilers should approach the data supplier and ask that the issues be addressed. If this fails, sources of the data, described above, can be used.

Following collection of data, all sources of data should be archived and documented together with any processing and any assumptions used for data collection. Archiving and documenting will allow the data to be reconstructed and will form the basis of future inventories. It is *good practice* to establish sustainable relationships with data producers to reduce the resources (human, time and financial resources) required for data collection in subsequent years.

Figure 2.0b (New) Outline of data collection steps and decisions



Maintaining supply of inventory data

Often working with a data provider benefits both the inventory and data provider. It is *good practice* to establish sustainable relationships with data producers to reduce the resources required for data collection in subsequent years. In some countries, developing close relationships with national statistical organizations will reduce the effort needed by the inventory compiler by utilising their knowledge and expertise in data collection. Developing long-term relationships with data suppliers can lead to improvements in the original data. Codifying data collection decision trees and collection steps with the data suppliers can lead to benefits for everyone. An improved understanding of the data could lead to improved inventories. Original data might be adjusted to better reflect reporting needs. Clarifying and documenting the inventory data requirements with data suppliers may help to secure the regular provision of resources within that organisation to provide the data to the required quality and on time in future inventory cycles (see Section 1.4.1 of Chapter 1).

It is *good practice* to engage data suppliers in the process of inventory compilation and improvement by involving them in activities such as:

- Offering an initial estimate for the category, pointing out the potentially high uncertainties and inviting potential data suppliers to collaborate in improving estimates.
- Scientific or statistical workshops on the inventory inputs and outputs.
- Agreeing specific contracts or agreements for regular data supply.
- Providing regular updates on the methods that use their data.
- Establishing of terms of reference or memoranda of understanding with data providers to clarify what is needed for the inventory, how it is derived and provided to the inventory compiler and when. Priority should be given to government authorized data providers.

These activities will help to ensure that the most appropriate data are available for the inventory and that the inventory compiler properly understands the data. It will also help to establish links to data providing organisations.

Where appropriate, it may be useful to explore existing or new legal arrangements as means of guaranteeing the delivery of data to the inventory.

Restricted data and confidentiality

Sometimes data may be provided to inventory compilers on a confidential or restricted basis. Confidential data can lead to an inventory lacking transparency and wherever possible the use of confidential data should be avoided. However, this is not always possible. Data providers might restrict access to information because it is confidential, unpublished, or not yet finalised. Typically, this is a mechanism to prevent inappropriate use of the data, unauthorised commercial exploitation, or sensitivity to possible imperfections in the data. Sometimes, however, the organisation simply does not have the resources required to compile and check the data.

The protection of confidentiality is one of the fundamental principles of a National Statistical Offices (NSO)[3]. NSO are committed to safeguarding information that plainly reveals the operations, belongings, attitudes or any other characteristics of individual respondents. If respondents are not convinced that the information they provide to the NSO is confidential, the quality of the information collected may suffer. Detailed individual data must therefore be treated and aggregated to draw out the information that is important to the user, without disclosing individual data. This is more likely to be an issue for business statistics, especially where a few companies dominate the sector, than for other data.

It is *good practice* that inventory compilers take the following steps to avoid this issue.

1. It is advisable, where possible, to cooperate with data providers to find solutions to overcome their concerns and allow the open use of the data by:
   (i) explaining the intended use of the data;
   (ii) agreeing, in writing, to the level at which it will be made public;
   (iii) identifying the increased accuracy that can be gained through its use in inventories;
   (iv) offering cooperation to derive mutually acceptable data sets;
   (v) and/or giving credit/acknowledgement in the inventory to the data provided.
2. There may be specific national mechanisms allowing use of confidential data in certain circumstances and these should be explored.
3. Sometimes, depending on the size and structure of the original sample, raw data can be aggregated in a way that protects confidentiality and yet produces useful information for emission inventory purposes. Aggregation techniques should be selected to avoid the possibility that the confidential data could be reconstructed using the published inventory. On the other hand, care should also be taken to minimize the aggregation as much as possible so as to be as transparent as possible. If, however, there is a need to preserve confidentiality the NSO,

[3] http://unstats.un.org/unsd/methods/statorg/ (UN, E/RES/2013/21).

or the body that originally collected the data, are normally the only ones that can carry out this additional treatment of the raw data. If masking or aggregating data is unsuccessful at preserving confidential data, it may be appropriate to look at other sources of data and avoid the use of confidential data favouring greater transparency of the GHG inventory, noting the need to ensure the quality of the inventory. Attention should also be paid to any reporting guidelines that might apply.

Some countries have special arrangements to mask data (i.e., make data anonymous with respect to companies or facilities) to allow researchers access. Inventory compilers may investigate the possibility of making such arrangements. However, as this reprocessing will be required regularly (annually if possible), a better solution would probably be for NSOs to incorporate this into their own work programmes. While this will require an initial investment in data processing, it will probably be quicker and less expensive in the long run. Once the reprocessing system is set up, it can be reused every time the survey is repeated, with low marginal costs. An added advantage is that the information will then be in the public domain so that others can validate the figures reported in the inventories.

Many agencies collect ancillary data during operations for other purposes, such as registration of businesses or vehicles, collection of taxes, granting of licences, allocation of grants and subsidies. Such information is usually also covered by confidentiality clauses. In general, such clauses foresee the use of the data for statistical purposes, and NSOs have the right of access to such data. Often these administrative data form the basis for sample stratification and selection and NSOs will have experience in handling them, perhaps even developing specialist software that allows the required information to be drawn out without breaching the confidentiality rules.

For all these reasons, when existing data need to be reprocessed, it is encouraged to work together with NSOs or the statistical service of the relevant ministry, not only to protect confidentiality, but also for cost savings.

BOX 2.0A (NEW)
EXAMPLE OF CONFIDENTIALITY AGREEMENT FORM OF THE UK IN 2013 (DECC AND DEFRA WERE THE RELEVANT GOVERNMENT DEPARTMENTS IN 2013)

Commercial confidentiality commitment:

As a part of Her Majesties' commitment: DECC and DEFRA preserves, protects and accounts for the information it holds and its information systems to a level which properly reflects the value and sensitivity of the information being processed, the relevant legal requirements, and Her Majesties' security policy and guidance.

We will use the information provided for the purpose of preparing the UK emissions inventory, undertaking analysis and presentation of data on and related to emissions and removals. DEFRA/DECC will assume all data provided is not confidential unless it has been identified as confidential in the annex. Where data is highlighted as confidential DEFRA/DECC will use all reasonable endeavours to protect this data (e.g. through aggregation).

Where you inform DECC and DEFRA that the information being provided is commercially confidential, DEFRA/DECC and the UK National Inventory Compiler will not disclose that information to any third party without your consent.

Where no exemptions exist to protect confidentiality, we may disclose data:

(a) where such disclosure is a requirement of law placed upon DECC and DEFRA.[a]

(b) where the information was in the possession of DECC or DEFRA without obligation of confidentiality prior to it being provided to DECC or DEFRA by you;

(c) where the information is already in the public domain at the time of disclosure;

(d) where the information is available to DECC and/or DEFRA on a non-confidential basis from a third party;

(e) where the information is independently developed by DECC or DEFRA without access to the information provided to DECC or DEFRA by you; or

(f) is requested by review experts nominated by the UN to review the UK emissions inventory(s) who have signed international agreements not to misuse or share confidential data clearly marked as confidential, solely for the purposes of review of the UK GHGI, or the UK NAEI.[b]

Organisation should inform us if specific issues relating to commercial confidentiality arise, and discuss with us to ensure that these issues do not interfere with publication of the inventory(s).

…

[a] Including any requirements for disclosure under the Freedom of Information Act, Data Protection Act or the Environmental Information Regulations; DECC and DEFRA are subject to the Code of Practice issued under s.45 of the Freedom of Information Act which covers consultation with affected parties before releasing information in response to a freedom of information request. DEFRA/DECC would like to reassure you that DEFRA/DECC will take full account of your desire that the information supplied to DECC is to be treated as commercially confidential, and, consequently, DEFRA/DECC will, in so far as possible, seek to notify you and obtain your views pending any disclosure in response to an information request, and take your views fully into account. The decision on whether or not to release information in response to an information request is a matter for Ministers making an objective decision about disclosure, having regard to the specific information in question, and the requirements and principles of the legislation. DECC and DEFRA general approach is to apply any exemptions robustly, while always fully complying with our legal obligations.

[b] In so far as DEFRA/DECC are able, DEFRA/DECC will use our reasonable endeavours to secure the destruction of the commercially confidential information by the review experts on completion of the review. In so far as DEFRA/DECC are able, DEFRA/DECC will also use our reasonable endeavours to prohibit the sharing of the commercially confidential information by the review experts with any other party.

BOX 2.0B (NEW)
ILLUSTRATIVE EXAMPLES OF AGGREGATION OF CONFIDENTIAL DATA

Each inventory compiler will need to find suitable categories to aggregate confidential emissions suited to their national circumstances.

Example 1: A country uses facility level data that are confidential to estimate emissions from large plant. These data are aggregated to a sector total so that the data remain confidential.

Example 2: A country has only one petroleum refinery and wishes to keep the refinery data confidential. It decides to report fugitive emissions under 1.B.2.a (Oil) combined with oil exploration, transport and distribution and the combustion emissions under 1.A.1.c (Manufacture of solid fuels and other energy industries) where the refinery emissions are obscured by the other emissions in this category.

Expert judgement

Expert judgement on methodological choice and choice of input data to use is ultimately the basis of all inventory development and sector specialists can be of particular use to fill gaps in the available data, to select data from a range of possible values or make judgements about uncertainty ranges as described in Section 3.2.2.3. Experts with suitable backgrounds can be found in government, industrial trade associations, technical institutes, industry and universities.

The goal of expert judgement may be choosing the proper methodology; the parameter value from ranges provided; the most appropriate activity data to use; the most appropriate way to apply a methodology; or determining the appropriate mix of technologies in use. A degree of expert judgement is required even when applying classical statistical techniques to data sets, since one must judge whether the data are a representative random sample and, if so, what methods to use to analyse the data. This requires both technical and statistical judgement. Interpretation is especially needed for data sets that are small, highly skewed or incomplete (Cullen & Frey 1999), (Frey & Rhodes 1996), and (Frey & Burmaster 1999). In all cases, the aim is to be as representative as possible in order to reduce possible bias and increase accuracy. Formal methods for obtaining (or eliciting) data from experts are known as expert elicitation, see Annex 2A.1 for details.

Despite endeavouring to collect all the data needed and document all of the data's associated uncertainties, there may be cases when no data is available and then the inventory compiler will need to rely on expert judgement to provide the information. Experts should be asked to estimate the missing data based on their expertise. In order to initiate such discussions and to provide a starting point for their considerations the following inputs can be used:

- If there are other countries with sectors in a similar stage of economic development, management practices and/or soil-climatic conditions, consider extrapolating from the similar country's reports.
- Experts might be able to infer national data from regional information with uncertainties.
- There may be information that is statistically or physically related to the parameters needed (e.g. industrial production is generally correlated with fuel consumption).
- Consider if the source exists. Some industrial sources may not occur in all countries. International data on trade and production often provide ways to confirm the existence of an industry within the country.
- If the category is likely to be very small compared to other categories, order of magnitude estimates can be made and used.

2.2.1 Gathering existing data

Although the list below is not exhaustive, it provides a starting point for possible sources of country specific data:

- National Statistics Offices.
- Sub-national or regional statistical agencies (e.g. provincial ministries or municipal governments that may have a mandate to collect relevant data).
- Facility level emission data. Such data as that reported e.g. to Pollutant Release and Transfer Registers (PRTR), or the European Union Emissions Trading System (EU ETS) may sometimes be used for estimating emissions from industrial installations but usually could not be directly reported in the GHGs emission inventory. See Section 2.3 for appropriate use of facility data in the inventory.

- Expert information, such as:
  - (i) sectoral experts, stakeholder organisations (e.g. industry and trade organizations, large-scale industries such as energy producers and Petro-chemical plant);
  - (ii) other national experts;
  - (iii) other international experts such as emission inventory sector experts from other countries with similar national circumstances.
- IPCC Emission Factor Database.
- Reference libraries (National Libraries).
- Scientific and technical articles in environmental books, journals and reports.
- Universities.
- National Inventory Reports from Parties to the United Nations Framework Convention on Climate Change.
- International organization published statistical databases such as:
  - (i) United Nations statistical databases[4];
  - (ii) Eurostat[5]. Key European statistics including emissions of GHGs;
  - (iii) The International Energy Agency[6]: Global energy statistics;
  - (iv) The Organisation for Economic Co-operation and Development (OECD)[7]. Global statistics on economic indicators in different sectors, GHGs emissions;
  - (v) The International Monetary Fund (IMF)[8]. Global economic and financial data;
  - (vi) The Food and Agriculture Organization statistics (FAOSTAT) including Database for agricultural statistics[9], Emissions Database for AFOLU[10], Global Forest Resources Assessment (FRA)[11]. Additional explanation on the use of FAO data in the GHGs inventory could be found at the Report of Joint FAO-IPCC-IFAD Expert Meeting (IPCC, FAO, IFAD 2015);
  - (vii) The International Fertilizer Association (IFASTAT)[12];
  - (viii) The International Rice Research Institute (IRRI)[13].
- Remote sensing data, e.g. geospatial products for land use, land management, soils and climate; GHGs measurements. See Volume 4, Chapter 3 for details.

Potential data sources focusing on developing countries could also include: Harmonized world soil database (FAO, IIASA, ISRIC, ISSCAS and JRC 2012) and GlobalSoilMap.net project, WorldClim, NEO and CRU, GLCC-IGBP, MODIS, Land Use/Cover Area Survey LUCAS by Eurostat, Regional Centre for Mapping of Resources for Development in Africa RCMRD, International Rice Research Institute (IRRI) which provides CH_4 emission measurements from major rice producing countries including China, India, Indonesia, Thailand, Philippines, etc. These data may be available by web search and data sets can be used for preparing GHG inventories for developing countries as well as other regions.

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[4] https://unstats.un.org/unsd/databases.htm.

[5] https://ec.europa.eu/eurostat/.

[6] https://www.iea.org/.

[7] http://www.oecd.org/.

[8] https://www.imf.org/en/data.

[9] http://www.fao.org/faostat/en/#home.

[10] http://www.fao.org/faostat/en/#data/GT (Agriculture emissions) and http://www.fao.org/faostat/en/#data/GL (Land Use emissions).

[11] http://www.fao.org/forest-resources-assessment/en/.

[12] https://www.ifastat.org/.

[13] http://ricestat.irri.org:8080/wrsv3/entrypoint.htm.

Some sectoral specific data sources are provided in the relevant chapters of Volumes 2-5 and also in the Annex 2.A.2.

The main principles of data collection and priority are discussed below.

Screening of available data

It is best to start data collection activities with an initial screening of available data sources. Inventory compilers need to identify and communicate with data providers in their countries. This will be an iterative process where details of data that are available are built up. This screening process may be slow and require questioning until a final judgement can be made about the usefulness of a data set for the inventory.

The purpose for which data were originally collected may be an important indicator of reliability. Regulatory authorities and official statistical bodies have a responsibility to take representative samples and accurate measurements, and so they often adopt agreed standards. Often official statistics (because they have a more elaborate review process) take a long time to become available but preliminary data may be available at an earlier stage. These preliminary data can be used if their validity is documented and can be checked against the data quality objectives set by the quality management system described in Chapter 6.

Refining Data Requirements

Once the inventory compiler has selected a data set, unless published data simply can be used in their original form, the next step will be to develop a more formal specification and data request and engage in cooperation with data suppliers to provide tailored data sets from their information. This formalisation enables efficient annual updating (through knowing what to ask for, from whom, and when) while complying with QA/QC requirements for documentation (see Chapter 6, QA/QC and Verification). A clear definition of data requirements will ensure that when data are delivered as expected. The specification should include details such as:

- definition of the data set (e.g., time series, sectors and sub-sector detail, extent of coverage, requirements for uncertainty data, emission factors and/or activity data units);
- definition of the format (e.g., spreadsheet) and structure (e.g., what different tables are needed and their structure) of the data set;
- description of any assumptions made regarding national coverage, the sectors included, representative year, technology/management level, and emission factors or uncertainty parameters;
- identification of the routines and timescales for data collection activities (e.g., how often is the data set updated and what elements are updated);
- reference to documentation and QA/QC procedures;
- contact name and organisation;
- date of availability.

It can be useful to seek commitment to these specifications from the organisation providing the data. Maintaining and updating these specifications on a regular basis, in case data requirements change, can also help to document the data sources and provide up-to-date guidance for routine data collection activities. It is not unusual for the delivery of data sets to be delayed so incorporating early warning routines to detect and manage delays can be useful.

Choosing between national and international data

In most cases it is preferable to use national data since national data sources are typically more up to date and provide better links to the originators of the data. Most international data sets rely on nationally derived data. In some cases, groups such as international trade associations or international statistical bodies will have country specific data sets for industries or other economic sectors that are not held by national organisations. Often international data have undergone additional checking and verification and may have been adjusted with the aim of increasing consistency, though this will not necessarily lead to improved estimates if the adjusted data are recombined with national information. Countries are encouraged to develop and improve national sources of data to avoid being reliant on international data. Crosschecking national data sets with any available international data can help to assess completeness and identify possible problems with either data set. Problems with international statistics and their use in the inventory compilation are mainly related to the level of disaggregation reported of parameter/data, their definitions, the use of units of measures and conversion factors used. Therefore, the inventory compiler, when considering international sources, should pay attention to all these factors. When cross checking national and international data sets, any adjustments made to national totals for inventory purposes (e.g., removal of bunker fuels) should be taken into account. Countries may use international data for inventory purposes where the national data are sparse or unavailable.

Surrogate data

It is preferable to use data that are directly related to the item being quantified rather than to use surrogate data (i.e., alternative data that have a correlation with the data that they are replacing). The term 'proxy variable' is also often used in statistical literature. In some cases, however, directly applicable data may be unavailable or have gaps (e.g., if survey and sampling programmes may be infrequent). In these cases, surrogate data can help fill gaps and generate a consistent time series or a country average. For example, where a country has information to apply a higher tier method for some but not all of its facilities, then surrogate data can be used to fill the gaps. The surrogate data should be physically and statistically related to the emissions from the set of facilities for which information is not available. These alternative data should be selected based on country-specific circumstances and information, and a relationship between the data and emissions (i.e., an emission factor) developed using information from a representative subset of facilities whose emissions are known. The use of surrogate data to obtain an initial estimate of an emission or removal can help prioritise resources.

In selecting and using surrogate data to estimate emissions or removals, it is *good practice* for countries to perform the following steps:

- confirm and document the physical relationship between emissions/removals and the surrogate activity data;
- confirm and document a statistically significant correlation between emissions/removals and the surrogate activity data;
- using regression analysis, develop a country-specific factor relating emissions/removals to the surrogate data.

An example of this approach is given in Box 2.1 and further explanation and equation (Equation 5.2) given in Section 5.3 of Chapter 5, Time Series Consistency of the *2006 IPCC Guidelines*.

BOX 2.1
EXAMPLE OF USING ALTERNATIVE DATA TO APPROXIMATE ACTIVITY DATA

The U.S. receives emission estimates for SF_6 associated with electrical equipment based on a mass-balance approach from electric power systems representing about 35 percent of the total length of U.S. transmission lines. (In the U.S., transmission lines are defined as lines carrying electricity at or above 34.5 kV). To estimate emissions from the remaining systems, the U.S. uses kilometres of transmission lines as alternative activity data. In the U.S., SF_6 is primarily used in equipment rated at or above 34.5 kV, and kilometres of transmission lines are therefore expected to be a good predictor of emissions. In addition, statistical analysis has demonstrated a high correlation between emissions and kilometres of transmission lines. Given these relationships, the U.S. uses regression factors relating transmission kilometres to emissions. These factors are then applied to the total transmission kilometres of the systems whose emissions are being estimated. Germany has also used the length of transmission lines to estimate emissions from closed pressure systems for a set of utilities that did not respond to an industry survey. Estimates are based on the electric power systems from utilities for which both transmission kilometres and emissions data were available. The resulting estimates were later confirmed by more comprehensive surveys in subsequent years. Information on equipment banks, available nationally from equipment manufacturers and distributors were used to estimate emissions from sealed-pressure systems). Transmission kilometres are likely to be a good predictor of emissions where most SF_6 is used in high voltage transmission equipment, as in the U.S. Where a high percentage of SF_6 is used in medium voltage distribution equipment or in gas-insulated substations, another type of data may be appropriate, such as the combined length of transmission and distribution lines or the number of substations. Combinations of these or other types of data may also be used although this increases the probability that one or more of the types of data will not be available for all the systems whose emissions are to be estimated.

2.2.2 Generating new data

It may be necessary to generate new data if representative emission factors, activity data or other estimation parameters do not exist, or cannot be estimated from existing sources. Generation of new data may entail measurement programmes for industrial process or energy related emissions, sampling of fuels for carbon content, land-use change and forestry sampling activities, or new census or surveys for activity data. Generation of new data is best undertaken by those with appropriate expertise (e.g., measurements carried out by competent organisations using appropriately calibrated equipment or surveys and censuses by any national statistical authority). These activities are often resource intensive and are most appropriately considered when the category is *key* and there are no other options. To optimise resource use it is recommended as far as possible to generate the required data from an extension of existing programmes rather than the initiation of very new ones. More specific details for activity data and emission factor are outlined in the respective sections of this chapter (2.2.4 and 2.2.5). Where guidelines exist for activities that are defined in detail by other official bodies, such as statistical offices and measurement standards committees, these are also referenced in these sections.

Generating data by measurement

Measurements should be used in the context of advice in the sectoral Volumes 2-5, for example to determine or revise emission factors, destruction/abatement efficiency factors and activity rates. Measurements can also be used to quantify greenhouse gas emissions directly or to calibrate and verify models that are used to generate data.

When considering using measurement data it is *good practice* to check whether it covers a representative sample, i.e., that is typical of a reasonable proportion of the whole category – and whether a suitable measurement method has been used. The best measurement methods are those that have been developed by official standards organisations and field-tested to determine their operational characteristics.[14] Using standardised measurement methods improves the consistency of measured data and provides the inventory compiler with additional information about the method such as statistical uncertainty levels, lower detection limits, sensitivity, and upper limits of measurement etc. The International Standards Organisation (ISO) standards, European Standards (EN) or suitable validated national standards of, e.g., U.S. Environmental Protection Agency (US EPA), or the Association of German Engineers (Verein Deutscher Ingenieure, VDI), may meet these criteria. It is *good practice* for the inventory compiler to document any measurement or quality management standards that have been used, and to bear in mind the data requirements of the uncertainty analysis in Chapter 3, Uncertainties, of Volume 1.

Reliable and comparable results can be achieved using a well-designed measurement programme with defined objectives; suitable methods; clear instructions to the measurement personnel; defined data processing and reporting procedures, and adequate documentation. Table 2.1 sets out the elements of such an approach.

[14] For example, repeatability, reproducibility, detection limit, tolerance to interference etc.

TABLE 2.1 (UPDATED)
GENERIC ELEMENTS OF A MEASUREMENT PROGRAMME

Measurement objective	Clear statement of the parameter(s) to be determined, e.g., HFC-23 emissions from HCFC-22 production.
Methodology protocol	Description of the measurement methodology to be used. This should include: • The components to be measured and any associated reference conditions; • Methods to ensure that representative samples are taken that reflect the nature of the source category and the measurement objective [a]; • The identification of any standard techniques to be used; • The analytical equipment needed and its operational requirements; • Any source/sink or installation access requirements; • Any accuracy, precision or uncertainty requirements; • Data capture requirements to be met; • Calibration material and methods requirements; • QA/QC regimes to be followed.
Measurement plan with clear instructions to the measurement personnel	Measurement plan specifies for those carrying out the measurements that includes: • Number of sampling points for each parameter to be measured and how these are to be selected; • Number of individual measurements to be made for each sampling point and set of conditions; • Measurement dates and periods of the measurement campaign; • Reporting arrangements; • Additional source or process related information to be collected to enable data processing or interpretation of the results; • Conditions (or range of conditions) of the source (or for industrial plant the capacity, load, fuel or feedstock) to be met during the measurements; • Personnel responsible for the measurements, who else is involved and the resources to be used.
Data processing and reporting procedures, and documentation	Data processing requirements, including: • Reporting procedures that will form an account of the measurements, the description of the measurement objectives, and the measurement plan; • Documentation requirements to enable the results to be traced back through the calculations to the collected basic data and process operating conditions. • Document the representativeness of the measurement sample.

[a] When making eco-system measurements particular care is required in defining the sampling requirements – see Volume 4.

General guidance to ensure the quality of measured data to determine better emission factors and other parameters is provided in Section 2.2.2.

Relationship of data to models

Although models are frequently used to assess complex systems and can be used to generate data, models are a means of data transformation and do not remove the need for data to drive them.

2.2.3 Adapting data for inventory use

Whether using existing data, making new measurements or combining the two it is important to ensure that the level of detail and coverage of the data match, including sectors/process/abatement, location, land type, compound and years included.

Gaps in data sets

Greenhouse gas inventories require consistent estimates across time series and between categories. This section introduces approaches to fill gaps if data are missing for one or more years or the data do not represent the year or national coverage required. Examples of data gaps or inconsistencies and guidance for addressing them are presented below.

- *Filling gaps in periodic data:* Gaps in the time series will exist when data are available at less than annual frequency. For example, time consuming and expensive surveys relating to natural resources - such as national forest inventories - are compiled at intervals of every fifth or tenth year. Time series data may need to be inferred to compile a complete annual estimate for the years between surveys, and for fore- and back- casts (e.g., where estimates are needed for 1990 – 2004 and survey data are only available for 1995 and 2000). Chapter 5, Time Series Consistency, provides details on splicing and extrapolation methods to fill these gaps.
- *Time series revision:* In order to meet deadlines, statistical organisations may use modelling and assumptions to complete the most recent year of their estimates. These estimates are then refined the following year when all the data have been processed. Data may have been subject to further revision of historic data to correct errors or to update new methodologies. It is important that the inventory compiler look for these changes in the source data time series and integrate them into the inventory. Chapter 5 of this Volume contains more guidance on this issue.
- *Incorporating improved data:* While the ability of countries to collect data generally improves over time so they can implement higher tier methods, the data may not necessarily be suitable for earlier years for the higher tiers. For example, when direct sampling and measurement programs are introduced there may be inconsistencies in the time series, as the new program cannot measure past conditions. Sometimes this can be addressed if the new data are sufficiently detailed (e.g., if emission factors for modern abated plant can be distinguished from those of older unabated plant) and the historic activity data can be stratified using expert judgement or surrogate data. Chapter 5 provides more details on methods of incorporating improved data consistently across a time series.
- *Compensating for deteriorating data:* Splicing techniques, as described in Chapter 5 on Time Series Consistency, can be used to manage data sets that have deteriorated over time. Deterioration can occur as the result of changing priorities within governments, economic restructuring, or diminishing resources. For example, some countries with economies in transition no longer collect certain data sets that were available in the base year, or these data sets may contain different definitions, classifications and levels of aggregation. The international data sources discussed in the activity data section (see Section 2.2.5) may provide another source of relevant activity data.
- *Incomplete coverage:* When data do not fully represent the whole country, e.g., measurements for three of ten plants or survey data of the agricultural activity for 80 percent of the country, then the data can still be used but needs to be combined with other data to calculate a national estimate. In these cases, expert judgement (see Section 2.2 above for details) or the combination of these data with other data sets (surrogate or exact data) can be used to calculate a national total. In some cases, survey or census data are collected in a rolling national programme that samples different provinces or sub-sectors yearly with a repeat cycle that builds a complete data set after a period of years. It is recommended that, bearing in mind that time series consistency, assumptions made in one year must also apply to the other years, and that data providers be requested to compute representative yearly data with a complete coverage.

Combining data sets numerically

Sometimes an inventory compiler will be presented with several potential data sets to use for the same estimate e.g., a series of independent measurements for the carbon content of a fuel. If the data refer to the same quantity and were collected in a reasonably uniform manner, then combining them will increase accuracy and precision. Combination can be achieved by pooling the raw data and re-estimating the mean and 95 percent confidence limits, or by combining summary statistics using the relationships set out in statistical textbooks. It also is possible to combine measurements of a single quantity made using different methods that produce results with different underlying probability distributions. However, the methods for doing this are more complex, and in most cases, it will probably be sufficient to use expert judgement to decide whether to average the results, or to use the more reliable estimate and discard the other.

When using data that are not homogeneous (e.g., because of the presence of abatement technology at some plant but not others) the inventory estimate should be stratified (subdivided) so that each stratum is homogeneous and the national total for the source category will then be the sum of the strata. The uncertainty estimates can then be obtained using the methods set out in Chapter 3 by treating each stratum in the same way as an individual category. Inhomogeneity may be identified by specific knowledge of the circumstances of individual plants or technology types, or by a detailed data analysis, e.g., scatter plots of estimated emissions/removals against activity data.

Empirical data sets may contain outliers – data points that lie outside the main probability distribution and are regarded as unrepresentative. These may be identified by some rule, for example lying more than three standard deviations from the mean. Before taking this path, the inventory compiler should consider whether the apparently anomalous data do in fact indicate some other set of circumstances (e.g., plant in start-up conditions) that should really be represented separately in the inventory estimate.

Multi-year averaging: Countries should report annual inventory estimates that are based on best estimates for actual emissions and removals in that year. Generally, single year estimates provide the best approximation of real emissions/removals and a time series of single year estimates prepared according to *good practice* can be considered consistent. Countries should, where possible, avoid using multi-year averaging of data that would result in over- or under-estimates of emissions over time, increased uncertainty, or reduced transparency, comparability or time-series consistency of the estimates. However, in some specific cases that are described for specific sectors in Volumes 2-5, multi-year averaging may be the best or even the only way to estimate data for a single year. In cases where the inventory compiler finds it is impossible to acquire activity data for each year it is *good practice* to use the methods given for ensuring time series consistency (Chapter 5 of this volume). In the case of emission factors with high or uncertain annual variability then multi-year averaging can improve the quality of the overall estimate provided the underlying conditions and processes remain unchanged. For example, for the growth of various tree species in a year there may be much higher confidence in the average annual growth rate over a period of years, than in an individual year growth. Multi-year averaging applies to the emission factors or similar parameters, not activity data.

Non-calendar year data: It is *good practice* to use calendar year data whenever the data are available. If calendar year data are unavailable, then other types of annual year data (e.g., non-calendar fiscal year data e.g., April – March) can be used provided that it is used consistently over the time series and the collection period for the data is documented. Similarly, different collection periods can be used for different emission and removal categories, again provided that the collection periods are used consistently over time and documented this is acceptable. It is *good practice* to use the same collection periods consistently over the time series to avoid bias in the trend. Animal population data may, for example, have been collected in the summer and so may not correspond with the annual average. The data should be corrected where possible to represent the calendar year. If uncorrected data are used, it is *good practice* for the inventory compiler to make consistent use of either calendar year data or fiscal year data for all years in the time series.

Regional inventory data

In some circumstances, regional activity statistics and emission data sets are more detailed, up-to-date, accurate and/or complete than national data sets. In these cases, a regionally compiled and then aggregated inventory can result in a better quality inventory for a country than one compiled using averaged national statistics and data sets. In such cases, and in order to fulfil the requirements of *good practice*, inventories can be compiled entirely or in part on a regional basis provided that:

- Each regional component is compiled in a way that is consistent with *good practice* QA/QC, choice of tiers, time series consistency and completeness.
- The approach used to aggregate the regional inventories and fill any gaps at a national level is transparent and in line with the *good practice* methods provided in the guidelines.
- The final country inventory complies with the *good practice* quality requirements of completeness, consistency, comparability, timeliness, accuracy and transparency. In particular, the sector estimates calculated at different regions, and then aggregated in the final inventory, should be self-consistent. There should be no emissions or removals omitted or double counted in the aggregated inventory and the different parts of the inventory should use assumptions and data consistently as far as practical and appropriate.

2.2.4 Emission factors and direct measurement of emissions

For categories that are NOT *key categories*, the default values given in Volume 2-5 of these guidelines can be used. For *key categories* it is *good practice* to develop country specific emission factors[15], with the goal to improve the accuracy of relevant emissions and removals estimates. If there is insufficient information on emissions data, then it may be necessary that these countries undertake measurement programs in a cost-effective and robust manner. This section provides generic advice for the derivation or review of emission factors or other estimation

[15] Provided a Tier 2 or 3 method exists in the guidelines.

parameters; this includes specialised literature sources, using measured data, and further remarks on combining data sets. It is *good practice* when developing emission factors or other estimation parameters to follow the approach to data collection described in Sections 2.1, 2.2.1 and 2.2, and to:

1. Identify emission factors (EFs) which need to be developed.
2. Consider the main parameters affecting emission or removal rates as shown in Table 2.1a.
3. Develop a strategy for acquiring the data.
4. Collect data for these parameters, including their uncertainty.
5. Calculate EFs to use with the methodology provided in the sectoral chapters or develop a country specific model.
6. Verify that the obtained EF is representative of the national circumstances.
7. Prepare proper documentation on the data and methodology used for EFs estimation (see e.g., Ogle et al. 2013) and their uncertainty.

The main category specific parameters influencing the emissions and removals are listed in the Table 2.1a. For more detailed guidance on parameters influencing emission factors, see sector-specific guidance in Volumes 2-5.

TABLE 2.1A (NEW)
MAIN PARAMETERS THAT EFFECT EMISSIONS AND REMOVALS

Sector	**Category**	**Sub-Category**	**EF Sensitive parameters**
Energy	Fuel combustion	Stationary	CO_2: Variable attributes of fossil fuels including carbon content. CH_4 and N_2O: Control Technologies.
		Mobile	CO_2: Portion of biofuels, Variable attributes of fossil fuels including carbon content. CH_4 and N_2O: • Vehicle type and engine technology (including domestic aircrafts). • Emission control technologies fitted to vehicle types in the fleet. • Fleet age distribution. • Maintenance effects.
	Fugitive emissions	Coal mining and handling	• Characteristics of seams. • Mitigation Technologies.

TABLE 2.1A (NEW) (CONTINUED)
MAIN PARAMETERS THAT EFFECT EMISSIONS AND REMOVALS

Sector	Category	Sub-Category	EF Sensitive parameters
Energy	Fugitive emissions	Oil and gas	• Composition profiles of gases from particular oil and gas fields. • Equipment type and practices. • Efficiencies of the specific control measures used. • Maintenance – management. • Composition of reservoir.
IPPU (many processes do not occur in all countries)			• Technology types. • Composition of feedstocks. • Leakage rates in F-gases related sectors. • Emission reduction technology of N_2O emissions into the atmosphere. • Emission reduction technologies and their efficiencies. • GHG by-product generation rates. • Frequency and duration of process disturbances.
AFOLU	Livestock population and production system characterization	Enteric Fermentation	• Livestock species and categories. • Animal weight and weight gain. • Milk production, fat and protein content. • Quantity, quality and type of feed.
		Manure Management	• Type of AWMS (solid storage, anaerobic lagoons, anaerobic digestion, etc.). • Manure characteristics (nitrogen content, methane production capacity). • Timing and length of storage. • Annual, monthly and daily temperature averages and variations.
	Agricultural soils	Direct and indirect N_2O emissions from managed soils	• Synthetic fertilizers applied to soils. • Livestock manure applied to soils. • Urine and dung deposited on pasture, range and paddock by grazing livestock. • Crop residue incorporation (leguminous and non-leguminous crops). • Drainage/management of organic soils. • Soil cultivation management practices. • Water management information for rice. • Information about the irrigation management. • Climate.

TABLE 2.1A (NEW) (CONTINUED)
MAIN PARAMETERS THAT EFFECT EMISSIONS AND REMOVALS

Sector	Category	Sub-Category	EF Sensitive parameters
Waste	Solid Waste		• Total municipal solid waste per year. • Waste composition. • Climatic conditions. • Type and management of landfills.
	Wastewater handling		• Wastewater treatment technology in the country. • Country population. • Protein consumption or availability. • Industrial production. • Sludge and nitrogen removed from treatment. • Discharge location.
	Waste incineration		• Type of incinerated waste per year.

Volumes 2-5 provide advice on the selection and use of emission factors or other estimation parameters for specific categories.

Literature sources

Inventory compilers commonly rely on the available literature to find emission factors or other estimation parameters. Table 2.2 lists a variety of potential literature sources in order of descending likelihood of the data being representative and appropriate for national circumstances. For *key categories* it is *good practice*, for countries to use peer-reviewed, published literature relevant to their national circumstances because this should provide the most accurate representation of their country's practices and activities. If there are no country-specific peer-reviewed studies available, then emission factors contained in the Emission Factor Database (EFDB), or other literature values can be used. These factors should reflect national circumstances as far as possible. The order of presentation in Table 2.2 is indicative only, and inventory compiler should assess each data source individually to make a determination of suitability.

A literature review is a useful approach for gathering and selecting from among a variety of possible data sources. Literature reviews can be time-consuming because many lead to old data and in addition the use of conversion units may generate artificial differences. Journal papers can sometimes be accessible through web without a subscription and libraries may facilitate search and access. Specialised literature sources relevant to emission factors are:

- National and international testing facilities (e.g., road traffic testing facilities);
- Industrial trade associations (technical papers such as reports, guidelines, standards, sectoral surveys or similar technical material);
- National authorities with responsibility for regulating emissions from industrial processes.

Literature reviews should be fully documented so that the data used for the inventory is transparent (see Chapter 6, QA/QC and Verification). It is also helpful to record the sources not used, providing an explanation of why, to save time in later literature review activities.

TABLE 2.2 (UPDATED)
POTENTIAL SOURCES OF EMISSION FACTORS

Literature type	Where to find it	Comments
IPCC Guidelines	IPCC website	Provide agreed default factors for Tier 1 methods but may not be representative of national circumstances.
IPCC Emission Factor Database (EFDB)	IPCC website	Described in more detail below. May not be representative of processes in your country or appropriate for *key category* estimates.
EMEP/EEA Emission Inventory Guidebook (EEA 2016)	EEA (European Environment Agency website)	Useful defaults or for crosschecking. May not be representative of processes in your country or appropriate for *key category* estimates.
International Emission Factor Databases: US EPA	US EPA website	Useful defaults or for crosschecking. May not be representative of processes in your country or appropriate for *key category* estimates.
International Emission Factor Databases: US EPA	National reference libraries, environmental press, environmental news journals	Reliable if representative. Can take time to be published.
Country-specific data from international or national peer reviewed journals	National laboratories	Reliable. Need to make sure the factors are representative and that standard methods are used.
National testing facilities (e.g., road traffic testing facilities)	Industrial process regulating authority	Regularly updated and plant-specific. Quality is dependent on the regulatory requirements, which may not extend to the methods used for estimating/measuring.
Emission regulating authority records and papers, or pollution release and transfer registries	Specific trade association	Sector-specific and up-to-date. QA/QC is needed to check for bias in data and to ensure the test conditions and measurement standards are understood.
Industry, technical and trade papers	Publications, libraries, and Web search	
Other specific studies, census, survey, measurement and monitoring data	Universities (environmental, measurement and monitoring departments)	Need to make sure the factors are representative and that standard methods are used.
International Emission Factor Databases: OECD	OECD website	Useful defaults or for crosschecking. May not be representative of processes in your country or appropriate for *key category* estimates.

TABLE 2.2 (UPDATED) (CONTINUED)
POTENTIAL SOURCES OF EMISSION FACTORS

Literature type	Where to find it	Comments
Emission factors or other estimation parameters for other countries	National Inventory Reports from Parties to UNFCCC, other inventory documentation, web search, national library	Appropriate for inventory use. Useful defaults or for crosschecking. May not be representative of processes in your country or appropriate for *key category* estimates.
International Fertilizer Industry Association IFIA; Food and Agriculture organization of the United Nations	https://www.ifastat.org/databases http://www.fao.org/faostat/en/#data	Data can be used in national GHG inventories especially for developing countries.
Trade data	https://comtrade.un.org/	Repository of official international trade statistics and relevant analytical tables

IPCC Emission Factor Database

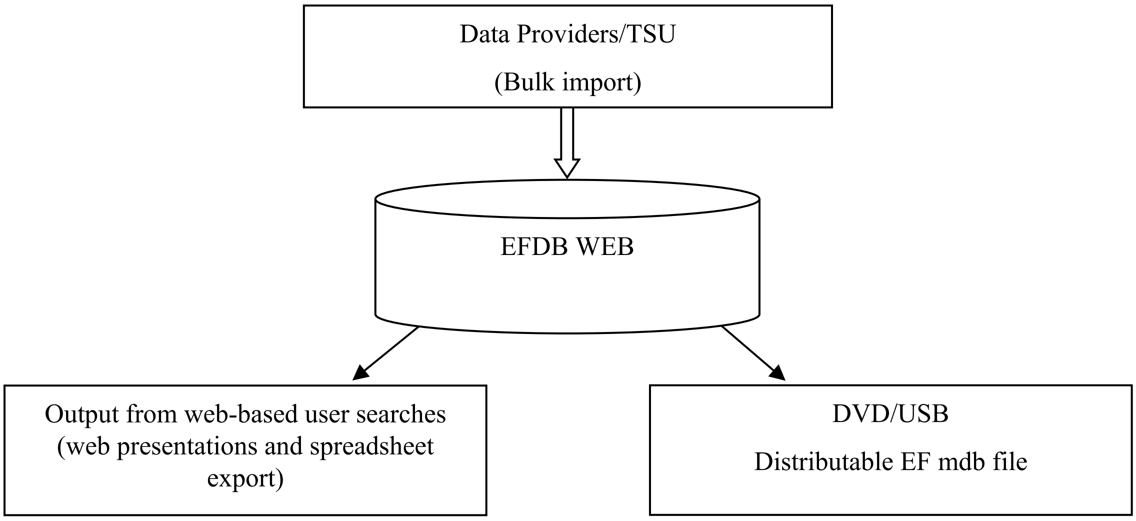
The Emission Factor Database (EFDB) is a continuously revised web-based information exchange forum for emission factors and other parameters relevant for the estimation of emissions or removals of greenhouse gases at national level. The database can be queried over the internet via the home pages of the IPCC, IPCC-NGGIP or directly at http://www.ipcc-nggip.iges.or.jp/EFDB/main.php.[16] The IPCC distributes a DVD with a copy of the database and a query tool at regular intervals.[17] It is designed as a platform for experts and researchers to communicate new emission factors or other parameters to a worldwide audience of potential end users. The EFDB is intended to become a recognised library where users can find emission factors and other parameters with background documentation or technical references. The criteria for inclusion of data in the database (see Figure 2.1) are:

- *Robustness*: The value would be unlikely to change, within the accepted uncertainty of the methodology, if there were to be a repetition of the original measurement programme or modelling activity.
- *Applicability:* An emission factor can only be applicable if the source and its mix of technology, operating and environmental conditions, abatement, and control technologies under which the emission factor was measured or modelled are clear, and allow the user to see how it can be applied.
- *Documentation:* Access information to the original technical reference is provided to evaluate the robustness and applicability as described above.

[16] Information, including manuals, on how to retrieve data from or contribute new data to the EFDB can also be found at this web site: www.ipcc-nggip.iges.or.jp/EFDB/.

[17] To receive a copy of the EFDB DVD, please contact IPCC NGGIP Technical Support Unit.

Figure 2.1 (Updated) Process for including data in the EFDB



Experts and researchers all over the world are invited to populate the EFDB with their data. The proposal of new emission factors (and other parameters) from data providers will be assessed by the Editorial Board of the EFDB for inclusion into the database. When the proposed new data comply with well-defined quality criteria of robustness, applicability and documentation they are included in the database. These procedures enable the user to judge the applicability of the emission factor or other parameter for use in their inventory and the responsibility of using this information appropriately however will always remain with the users.

Data obtained by measurements

This section applies the guidance in Section 2.2.2 to assessing the quality of measurement data for determination of emissions, emission factors and abatement or destruction efficiencies. Volume 4 provides specific guidance on the use of samples and surveys in Agriculture, Forestry, and Other Land Use (AFOLU) Sector.

In this approach the emissions can be determined directly (i.e., using continuous emission monitoring systems) or calculated. Where emissions depend on variable combustion, process and operating conditions, and technologies (e.g., methane and nitrous oxide from combustion), direct monitoring is likely to be the most accurate way to determine emissions.

When reviewing energy or industrial plant data, it is important to ensure that the measurements are representative of the specific activity and do not include extraneous components. For example, stack measurements may exclude losses to the atmosphere through evaporation or poorly burned fuel that is emitted as volatile organic compounds (VOC); these should be included in the reported emissions totals. More details of measurement issues are included in the Industrial Processes and Product Use (IPPU) Volume.

In implementing the elements of measurement programme identified in Section 2.2.2 is *good practice* to:

- distinguish between different components in a mixed fuel/raw material feed e.g., coal and wood in a mixed fuel boiler;
- specify how the chemical composition of fuels and raw materials should be determined from the analyses of samples taken from delivery trucks/tankers, pipelines, or stockpiles;
- ensure representative sampling of exhaust gases;
- use instruments with known performance characteristics or perform relative accuracy audits against established standard reference methods.

Most gas analysers determine the volume concentration of gaseous components (volume/volume) and so unless conditions can be shown to be stable it will be necessary to measure the exhaust gas flow rate, pressure, temperature, and water vapour content, so that the greenhouse gas emission can be converted to reference conditions for temperature and pressure (e.g., 273 K and 101.3 kPa, dry) or quoted on a mass emission basis. Other measurements are usually needed to calculate process specific conversion and oxidation efficiency factors and, if the fuel/raw materials used are not in dry weight, a moisture analysis will be required. Related measurements should be made simultaneously, or in such a way that ensures the correct functional relationship between the variables being sampled, otherwise integrated flows or emissions derived from the measurements are likely to be incorrect.

It is *good practice* to use scales, and flow meters, that are of a known quality, calibrated, maintained, and regularly inspected, when using measurements to calculate activity rates e.g., from measured fuel or raw material feed rates (or sometimes from production data). Measurement equipment can be of variable quality and it is important that there is regular maintenance and calibration procedures in place and that these are subject to regular QA/QC review. When recording is carried out on a continuous basis it is *good practice* to monitor and record any time when meters are not working and the data capture rate is reduced – the advice on gap filling (in Section 2.2.3, Adapting data for inventory use) can, however, enable imperfect data sets to be repaired sufficiently for some purposes – such as the generation of emission factors.

It is also *good practice,* as part of the measurement programme to include in the scope of a monitoring protocol how measurements are to be carried out, if the fuel/raw materials are not in dry weight or there are contaminants that could adversely affect the measurement process, or moisture content.

Quality management is an important factor to take into account. ISO 17025:2005 'General requirements for the competence of testing and calibration laboratories' describes a useful QA/QC regime for testing and measurement. It encourages the use of standard methods by qualified personnel using suitability-tested equipment. It also encourages a quality management system that should cover traceable calibration artefacts; taking and storing samples; any subsequent analysis; and the reporting of results. The standards listed in Table 2.3 are relevant to greenhouse gas emissions measurement and should be used where applicable.

TABLE 2.3 (UPDATED)
STANDARD MEASUREMENT METHODS FOR EXHAUST GAS

Index	**Existing international standard methods**	**Other widely used standard methods[4]**
CO_2	ISO 12039:2001 Stationary source emissions - Determination of carbon monoxide, carbon dioxide and oxygen - Performance characteristics and calibration of an automated measuring method[1] ISO 10396:2007 Stationary source emissions - Sampling for the automated determination of gas emission concentrations for permanently-installed monitoring systems	US EPA Method 3 - Gas analysis for the determination of dry molecular weight US EPA Method 3A - Determination of oxygen and carbon dioxide concentrations in emissions from stationary sources (instrumental analyser procedure)
CH_4	ISO 25139:2011 Stationary source emissions – Manual method for the determination of the methane concentration using gas chromatography	US EPA Method 3C - Determination of carbon dioxide, methane, nitrogen and oxygen from stationary sources Standard developed by ISO TC 264 - Air Quality
N_2O	ISO 21258:2010 Stationary source emissions - Determination of the mass concentration of dinitrogen monoxide (N_2O) - Reference method: Non-dispersive infrared method	Standard being developed by ISO TC 264 – Air Quality

TABLE 2.3 (UPDATED) (CONTINUED) STANDARD MEASUREMENT METHODS FOR EXHAUST GAS		
Index	**Existing international standard methods**	**Other widely used standard methods**[4]
Gas velocity	ISO 10780:1994 Air Quality - Stationary source emissions - Measurement of velocity and volume flow rate of gas streams in ducts. *S-Type pitot tube* ISO 3966:1977 Measurement of fluid flow in closed conduits - velocity area method using Pitot static tubes[2]. *L-Type Pitot tube* ISO 14164:1999 Stationary source emissions. Determination of the volume flow rate of gas streams in ducts -automated method. *Dynamic pressure method for continuous, in situ/crossduct, measurements*	US EPA method 1 - Sample and velocity traverses for stationary sources US EPA Method 1A - Sample and velocity traverses for stationary sources with small stacks or ducts US EPA Method 2 - Determination of stack gas velocity and volumetric flow rate (Type S pitot tube) (or alternatively Methods 2F, 2G, 2H and CTM-041)[5]
General[3]	ISO/IEC 17025:2005 General requirements for the competence of testing and calibration laboratories ISO 10012:2003 Measurement management systems - Requirements for measurement processes and measuring equipment	PrEN 15259:2005 Air Quality – Measurement of stationary source emissions - measurement strategy, measurement planning and reporting, and design of measurement sites EN61207-1:1994 Expression of performance of gas analyzers - Part 1 General
Index	**Standards under development**	
CO_2, CH_4, N_2O	ISO/FDIS 20951 Soil Quality - Guidance on methods for measuring greenhouse gases (CO_2, N_2O, CH_4) and ammonia (NH_3) fluxes between soils and the atmosphere	EN 14790[6] US EPA Method 4 - Determination of moisture content in stack gases
PFC, SF_6, HFC, FCs	None	(N.B. Where available sector specific methodologies are referenced in the sector specific volumes)

[1] This standard describes the performance characteristics, detection principles and the calibration procedures for automated measuring systems for the determination of carbon dioxide and other substances in the flue gases emissions from stationary sources. The reported concentration range of this standard is 6 - 62500 mg m^{-3} with a measurement uncertainty of <10 percent of the measured value.

[2] This standard has been withdrawn pending revision; nevertheless, it is widely used in the absence of anything better.

[3] While these standards are not associated with a reference method for a specific greenhouse gas category, they have direct application to QC activities associated with estimations based on measured emission values.

[4] US EPA Methods, e.g., Method 1, 1A, 2, 3, etc., are EPA test methods that are available in Title 40 of the Code of Federal Regulations CFR) Part 60, Appendices. These test methods are developed by the Office of Air Quality Planning and Standards in the Office of Air and Radiation. 40 CFR Part 60 is published each year by the Office of the Federal Register, and is available from the U.S. Government Printing Office. Although the test methods generally do not change from year to year, users should check for the most recent version of 40 CFR Part 60, Appendices.

[5] Methods 2F and 2G correct the measured flow rates for angular (non-axial) flow. Method 2H (for circular stacks) and conditional test method CTM-041 (for rectangular stacks and ducts) are used to correct the measured flow rates for velocity decay near the stack wall, using a 'wall effects adjustment factor'.

[6] Water measurement is needed to correct measured gas volume to standard 'dry' conditions.

2.2.5 Activity data

This section provides general advice for the production or review of activity data. This includes:

- information on specialised data sources;
- conducting surveys and censuses;

It is *good practice* when producing suitable activity data to follow the stepwise approach shown in Figure 2.0b. As explained in Sections 1.4 and 1.4a of Volume 1, Chapter 1 (“Inventory Quality” and “National GHG Inventory Arrangements” respectively), an important part of inventory compilation is continuous improvement. Thus, while data collection starts with *key categories* identified in earlier years, priorities should be reviewed by performing key category analysis on the new inventory. All data collected should be reviewed and assessed to check it is still suitable for use in the inventory. This section provides generic advice relevant to the choice of activity data to use.

Volumes 2-5 provide advice on the selection and use of activity data for specific categories.

Data Sources

National and International Literature

As described in Section 2.2.1, it is preferable to use data from such bodies as National Statistical Agencies, and national regulatory authorities responsible for the permitting of industrial and other processes subject to pollution emission legislation.

There will be occasions, however, when other sources of specialised literature provide activity data e.g. UN statistics, US Geological Survey (USGS) reports on commodities, and technical reports, guidelines, standards, sectoral surveys issued by industrial trade associations.

Surveys & Census information

Survey and census information (see Box 2.2) provide the best agricultural, production and energy statistics that can be used for greenhouse gas inventories. Generally, these data are compiled by national statistical agencies offices (NSA) or relevant ministries for national policy purposes or to comply with international demand for data, or other activities that are outside of the direct control of the inventory compiler although the needs of the inventory can sometimes trigger or influence surveys or censuses.

BOX 2.2
THE DIFFERENCE BETWEEN CENSUS AND SURVEY DATA

Survey data are derived from sampling and do not include real data for the whole population. Surveys should assess a representative sample (in the context of the survey purpose), so that the results can be expanded to provide an estimate of the full population. A survey could, for example, assess the number of animals in a country or region by surveying a discrete selection of farms and groups of farms in a country or region. Using more general surrogate data and assumptions would then derive the national or regional total. Both the representativeness of the sample and the methods used to gross-up need careful review.

Census data are based on a complete count of the whole population, i.e., an actual count of all the animals in a region or country. A census is usually limited in detail and diversity to only the most important national statistics such as human and livestock population. It is expensive and time consuming and this is a significant limiting factor for specific national inventory applications. Often census data are used as a reliable surrogate for extrapolating survey data to national statistics.

Using existing census and survey data: In some countries, data collection functions within a defined and often legally mandated national statistical system. In some countries the NSO is a single agency that is responsible for all national statistics, while in others the task is split among multiple agencies that form the national statistical system, each of which collect official statistics related to their field, i.e., a country’s agriculture ministry may be responsible for carrying out agricultural surveys and censuses. This has the advantage that the ministry is likely to have the specialist knowledge required to define adequately the data to be collected and to have at their disposal the administrative information to help stratify and select the sample to be surveyed, for example, a register of businesses working in the area covered by the remit of the ministry. In these cases, ministries may have their own statistics departments (or will work closely with any NSO) to provide the specialist with statistical knowledge, which is essential to avoiding many of the common pitfalls in data collection. Examples and information about national statistical agencies may be found through the websites of the UNSD[18] and the European Commission[19].

Where available these data sets can be used either directly (if they represent the geographical and sectoral coverage required) or as part of hybrid data set in combination with other information necessary to derive the detail and geographical coverage required.

Developing new Surveys: Developing new surveys, especially surveys of consumers or households, is relatively expensive because sample size and proper conduct of the fieldwork, data processing, analysis, and reporting are all demanding. Considerable effort would be required to check the reliability and consistency of data, even when response rates appear to be otherwise satisfactory. Unless they can be consistently repeated, surveys are only able to give measurements relating to one point in time. Bearing this in mind, and also taking into account the length of time such surveys take to design, execute and analyse - for the development of a major survey, planning typically starts about 18 months before data collection starts, with results available a year or more after the data collection period - attention should first be paid to the possibility of obtaining regular and consistent data from existing sources, such as recombining data collected for other purposes, or using administrative data.

Where new data collection is unavoidable, the NSO and/or the relevant ministry can identify what surveys are ongoing or planned, and can explore the possibility of adding new questions or modules to these surveys to fill the data gaps. One of the many advantages of working with a NSO or ministry is that they will design the method of collection and the questionnaire to take into account the needs of as many users as possible. This reduces costs as well as the burden on businesses and other respondents, making it more likely that they will complete the questionnaire. Also, selecting the survey sample requires a reliable sampling frame, for example, census data or business registers. The NSO or relevant ministry will have ready access to such sources, and experience in using them. They will have teams of qualified and experienced statisticians, experts in sample selection, questionnaire design, data handling and verification, and the necessary software to process the data. They may also have teams of interviewers experienced in telephone or personal surveying. All of these factors contribute to the success of any survey and equally importantly, to keeping costs down.

General Guidelines for Planning Surveys & Census: It is *good practice* to plan each step with all subsequent steps in mind, from data collection, processing and analysis to dissemination of output. For example, the questionnaire and other data collection procedures should be developed only after thinking through how the data will be processed and analysed, and the nature of the statistical information that will eventually be reported. In particular, planning needs to cover:

- *Budget issues:* Costs will always be a major consideration. The total budget needs to be calculated and resources allocated to each phase of the process. Uncontrolled spending on each phase until the budget is depleted can lead to the collection of data without the necessary resources to produce and disseminate high quality output.
- *Staffing issues, including management of the interviewer workforce:* Staff resources need to be planned to ensure that people with the right skills are available at the appropriate times in all phases of the process. If interviewers are used rather than self-completion questionnaires, the interviewer workforce is likely to be the largest single cost in the collection.
- *Project management and timetable issues:* Good project management is essential to ensure a smooth-running collection. Adequate time needs to be allocated to each phase of the collection process. A thorough pre- testing of the questionnaire will help ensure that the data collected are reliable and valid.

The American Statistical Association's information is a useful source of help when setting up a new survey[20], The UN's guidelines for conducting household surveys in developing and transition countries provide detailed information on how to set up sample surveys based on direct questions to households[21]

Moreover, many organisations contribute to statistical capacity building and will provide assistance to developing countries wishing to set up new surveys; the UNEP, UNDP, and the World Bank are the implementing agencies of the Global Environment Facility.

[18] https://unstats.un.org/unsd/dnss/cp/searchcp.aspx.

[19] https://ec.europa.eu/eurostat/documents/747709/753176/20180719_List_ONAs_LV.pdf/0e48549e-f3a0-4b86-a1c7-aae7e6468a84.

[20] http://www.amstat.org/.

[21] http://unstats.un.org/unsd/HHsurveys/part1_new.htm.

References to guidance on statistical data and surveys for energy, industrial processes, agriculture, forestry and waste are given in the Annex 2A.2.

Three important steps are needed before deciding whether a survey is required, and what modules it should contain:

- Review what data are likely to be available through existing data systems, including planned surveys. Remember that published statistics are based on detailed data that have been treated and aggregated to draw out the information that is important to the main user. In some cases, depending on the size and structure of the original sample, those raw data can be recombined in different ways to produce data that are appropriate for another user.
- Explore administrative sources of data. While the administrative records may not initially be easy to use for inventory purposes, once the system has been reorganised and restructured to produce the relevant data, it can become the regular source of the relevant information, at little marginal cost. More and more countries are beginning to realise the cost benefits of using administrative data for statistics, and in some cases, National Statistical Offices are obliged by law to explore the use of administrative data to provide statistics before deciding to launch an expensive new survey.
- Explore the possibility of incorporating new questions or modules into existing surveys.

If, after exploring the possibility to make use of existing data, data gaps still remain, then approach the NSO or ministry about carrying out a new survey. Provided the financial resources are made available, the NSO or ministry will be able to provide the all-important expertise. Also explore whether other partners might be interested in sharing the work and resources needed for it.

2.3 USE OF FACILITY DATA IN INVENTORIES

2.3.1 Introduction

Detailed industrial facility data, which is increasingly collected for various goals such as tracking the progress of emission trading programmes or climate change policies, may be utilized in national inventories. When generated and collected appropriately, facility-specific data may be considered and used by national inventory compilers in multiple ways, from replacing a subset of data to forming a significant portion of the inventory, including GHG emission estimates, activity data and emission factors to better reflect country-specific industrial context while increasing the overall quality of the inventory.

Facility data may also be used to evaluate, compare or support national inventory methods for a specific greenhouse gas, source, or industrial category and used in conjunction with other data sources such as industry studies to better reflect national circumstances. Facility data may over time better reflect an industry's emission trends, as compared to the use of constant emission factors, for example, since these emission factors may not take into account operational changes resulting in varying GHG intensities (emissions per unit of output).

Data provided by facilities through pre-existing programmes is not usually designed for the purpose of meeting GHG inventory compilation needs. Thus, there may be transparency, consistency and comparability deficiencies that inventory compilers will need to take into consideration. To reduce reporting burden and increase the use of facility data in an inventory, where possible, collaboration with the existing reporting programmes to enhance the collected data is encouraged. If this is not possible, national compilers can still assess the quality of the available information and how best to apply it. For example, some of the information may help increase the level of disaggregation of activity data, improve emission factors or provide new parameters to support higher-tier approaches for a specific source category (e.g. fuel NCV, carbon content or industrial production data).

Data are also collected for research projects or studies, and these data, if available to the compiler, can also be assessed for inventory use. These types of data are generally obtained from one-off activities[22], as compared to annually-collected facility data, and the information is usually too specific to a process/operation to support full integration of its results across a whole industrial category. For additional options for the use of these data see Section 2.3.4, Uses of facility data not originally designed for inventory application.

It is important to note that integrating facility reported data (FRD) into a national emission inventory is optional and should only be considered if the information improves the quality of the inventory and better reflects national circumstances. National inventory compilers should not assume that facility level data is by default an

[22] One-off studies or research usually comes with a time-series consistency issue that needs to be taken into consideration. Also, these research projects or studies generally focus on a specific industrial operation or emission source.

improvement on estimates based on national statistical activity data, due to possible reporting biases, especially if activity data are not properly measured or when IPCC default emission factors [23] that do not take into account facility-specific operation and processes, are used. Bias may also be present if measurement methods are similar across industry and do not account for facility-specific operation and processes. National inventory compilers must assess and assure that the information of interest is of high quality with low bias.

Although the primary focus of this section is to provide guidance on integrating industrial facility data for the Energy and IPPU sectors into national GHG inventories, these integration concepts and guidance can be adapted to most other IPCC sectors (e.g. Waste) and categories (e.g., wastewater treatments or landfills).

FRD could support the development of higher tier IPCC methodologies; however, a higher tier method is not always needed. The added burden of developing a Tier 3 facility-specific approach may not be worthwhile if the same level of quality or accuracy can be achieved more efficiently or cost-effectively by instead improving the primary activity dataset or updating emission factors, as two examples.

2.3.2 Designing facility-reporting programmes for inventory use

This section presents design elements along with collaborative approaches when considering how best to utilize and integrate facility data from regulatory GHG reporting programmes developed primarily for other purposes.

To ensure high quality information is available for integration, it is best achieved through appropriate design of the Facility-Reporting Programmes (FRP). Inventory compilers and legislative groups developing reporting systems are encouraged to work together to streamline and design an efficient system that meets national inventory and legislative goals while limiting collection and reporting burden. A discussion on the importance of collaboration between relevant organisations responsible for the compilation of national statistics or activity data and the GHG inventory is included in Section 2.3.2.2. The proposed approach is to help gain efficiency in the collection and use of facility reported data (FRD) across multiple purposes. Collaboration between organisations in establishing a set of essential requirements and definitions will ensure common interpretation of reported information by all users and reporters. This should streamline reporting elements and data sharing when a decision to incorporate specific FRD into the national GHG inventory following data quality review is made.

The approach outlined in this section focuses on specifically incorporating the collection of data for inventory purposes into the design of the FRP. However, this approach can also assist compilers to assess facility data, obtained from programmes primarily designed for other purposes, for its use in GHG inventories.

2.3.2.1 FACILITY-REPORTED DATA

The quality of Facility reported Data (FRD) is dependent on the type of data collected as well as its accuracy, level of detail and transparency. This section is focused on elements to consider when establishing reporting requirements for attainment of quality industrial FRD.

The quality of industrial facility-reported information is dependent on the type and availability of the information to be collected, and the design of quantification methodologies, emission monitoring methods and verification activities. Specifying the information to be reported (such as fuel quantity, carbon content, heat content, etc.) and methods appropriately, will assist in achieving the quality and transparency required for the type of inventory integration intended.

Quality Criteria and Reporting Elements

Even with independent third-party verification of FRD, the use of these data in a national GHG inventory may not be possible due to insufficient reported information or a lack of transparency, both of which can limit the ability to conduct adequate quality assessments. As a starting point in the development of facility-reporting requirements, inventory compilers should consider how to align methodologies to be applied and types of data to be reported with IPCC quality principles:

- Methodologies – facility GHG estimation methods to be applied must be at least comparable with, or of a higher tier than current inventory approaches for a specific industry type or common emission source.

[23] When default IPCC emission factors are used, compilers should assess if the estimate is better in quality as compared to the inventory before directly integrating facility-reported emissions. Compilers may also, consider the use of reported activity data or other parameters, if it improves the quality of the emission estimate.

- Alignment of activity data – facility fuel consumption and production data should be equivalent to a subset of the national datasets for compilers to properly take into account each facility's contribution relative to the whole for each industry type. Collaboration with national activity data compilers is important in ensuring that FRD is a subset or is used in the development of the national dataset, allowing for direct integration of FRD while addressing potential completeness issue. Elaboration on alignment concepts and use of activity data is presented in Section 2.3.2.2, Table 2.4, Equation 2.3 and Figure 2.2.

In designing methodologies[24] and reporting requirements for potential integration of facility it is *good practice* to achieve quality through the application of inventory principles. That is, design goals should be set to ensure that data from each facility would be complete, transparent, accurate, comparable, and consistent.[25] Some of these quality goals are shown in Table 2.4.

[24] Specifying methods and the use/development of site-specific factors and engineering approaches can also contribute to improve transparency and quality of reported data. To support FRD assessment, when facility specific method(s) is applied, additional reporting requirements and supporting documentation of approaches is required from FRP for transparency purposes.

[25] It is also *good practice* to review facility-reported supporting documentation, apply quality assurance/quality control measures to the data and assess its uncertainty.

TABLE 2.4 (NEW) QUALITY GOALS FOR FACILITY DATA	
Inventory Principle	**Quality Goals**
Comparability	• Methods align with inventory and are of equal or higher tier. • Methods across common industry are of equal or higher tier/Facilities in same industry use similar methods with consideration of operation or process differences. • Facility activity data aligns with national statistics and other inventory data (e.g: International Standard Industrial Classification (ISIC), Standard Industrial Classification (SIC), or North American Industrial Classification System (NAICS) categorization). • Facility categories align with inventory (e.g. IPCC category/subcategory).
Consistency	• Facility activity data to be reported across similar sectors/categories and by industry type should have the same reporting units of measure corrected to the same operating condition (e.g. temperature and pressure for gaseous fuels or moisture content for solid fuels). • Time series demonstrate consistency by source type and by type of greenhouse gases.[26] • Reporting facility and information should align with those of the national data agency.
Accuracy	• Activity data is accurate (e.g., fuel measurements are clearly stipulated, possibly based on standardized or regulated measurement and metering standards). • Primary emission factor is accurately determined based on accepted standardized measurement and sampling approaches (e.g. ASTM). • Emission estimates for facilities covered are at least as accurate as inventory methods.
Transparency	• Methodology applied is documented and clearly explained when different from specified approach. • Activity data and emission estimates are documented and clearly explained when different from specified measurement and sampling approaches. • Emission factors are documented and clearly explained when different from specified approach (e.g. plant/source specific emission factors determined transparently). • FRD should be reported at a sufficient level of disaggregation for assessment and use. For example, where a facility reports emissions from more than one emission source category (e.g. a cement kiln reporting combustion emissions (Energy) and process emissions (IPPU)), then AD, EFs and emissions should be reported separately for these source categories. • Reported/archived data allows for full verification.
Completeness	• FRD (reported emissions, fuel quantities, emission factors and other parameters) can be integrated into inventory, ensuring complete sector, category, and/or subcategory coverage. • Industrial coverage – percentage of reported facilities relative to total industry (for a same SIC or NAICS categorization) is considered (greater coverage by facility data implies higher resultant inventory quality). • Reported information should cover all emission sources occurring at the facility and in cases where it does not, facility to clearly specify sources that are not included along with explanation.

As identified in Table 2.4, these quality goals cannot be pursued in isolation of one and other. For example, if a methodology is comparable with the inventory method, this does not ensure that the facility-reported information will improve the quality (or reduce the uncertainty) of inventory estimates. A review of emission factors and activity data may demonstrate that industry specific operating conditions should be taken into account to compile and generate representative data. The following are some recommended means of obtaining quality facility data for inclusion in methodological or measurement specification: direct measurement of fuel, feedstocks and production quantities based on calibrated metering systems; standardised sampling methods of evaluating the carbon content of fuels and feedstock; standardized methods of measuring emissions of GHGs from vents and correlating these with activity data measurements to develop emission factors; obtaining information about on-site technologies based on age, type, efficiency or operational load changes; measurement of the leakage rates of plant equipment, including seasonal variations.

[26] Break in time series consistency is possible for various reasons such as operational changes, new material input, installation of new technology, etc. Data compilers should confirm with reporters as part of the QA/QC process of FRD for explanation/justification to the break in time series.

Where methods are used that do not meet recognised standards, a report describing facility specific methods (such as engineering approaches, site specific emission factor development etc.), measurement techniques (that deviate from standards) and assumptions should be provided to allow transparent understanding of the basis of the data. Where methods do not meet national regulatory requirements, or recognised standards, national inventory compilers should only use the data if they can be assured that facility specific methods will result in quality data that would be equivalent to or better than those resulting from national regulatory requirements, or recognised standards. When facility specific method(s) is found to be deficient, national inventory compiler(s) is encouraged to work with regulator and where possible reporting facility to better understand and resolve issues as to increase data quality.

Establishing Quality through Reporting Specifications

As implied above, in order to obtain quality information, appropriate methods and reporting requirements must be established. Table 2.5 below is not an exhaustive list, but a starting point to identify reporting requirements in support of obtaining quality data. It is based on methodological and data concepts drawn mainly from the Energy and the IPPU Volumes of these guidelines. Inventory compilers will need to identify their specific methodological and data requirements based on their own inventory quality requirements.

TABLE 2.5 (NEW)
POTENTIAL FACILITY GHG REPORTING REQUIREMENTS

Methodological Specifications	Reporting Elements
• Methods should be, at a minimum, equivalent to inventory methods or better for each source type or activity level. • Measurement or metering approaches should follow regulated standards. • Fuel/product sampling should follow regulated standards to take into account variable carbon content of fuels, process feedstock and product output. • On the basis of inventory information, country-specific/default emission factors should be provided for fuels/product with low variation in properties.	• Methods for each source and emission type. • Documentation of approaches when inconsistent with specified methods. Provide supporting documentation for review and consideration. • Quantity of each fuel and process input or production output by source type. • Emission factor by gases, by source type or by fuel type. • Carbon content for each type of variable fuel and process feedstock. • Fuel properties (e.g., heat content, temperature, pressure, moisture content when relevant). • Emission destruction efficiency. • Carbon dioxide capture and injection volumes (along with percent CO_2 concentration). • Any other parameters that will affect emission levels.
• Allow use of continuous emission monitoring (CEM) systems and specify calibration and testing requirements.	• Emissions by gases from each CEM system. • Identification of sources captured by each CEM system. • Activity data (such as quantity of each fuel and process feedstock) and information on any emissions controls, which contributes to emissions measured based on the CEM system.
• Source specific methods (i.e., stationary fuel combustion, off-road combustion equipment, coke oven battery, clinker production, wastewater treatment, etc.). • GHG specific methods (i.e. CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3).	• Emission by GHG and corresponding source type.
• Specify industrial categories that align with national statistics classification (i.e. International Standard Industrial Classification, Standard Industrial Classification, North American Classification).	• Industrial classification of facility.
• Consider setting a *de minimis* allowance[27, 28]. It can be based on the total emissions of a facility or by source and GHG, and may be specified as a percentage of all GHGs or by type of GHG (e.g. 1 percent of total CO_2 from fuel combustion). The *de minimis* should in no case be set larger than the absolute value of the uncertainty. • Supporting documentation - document methods and assumptions when methods are not in line with FRP's requirements.	• List by source type not reported (i.e., fuel combustion – off-road vehicles diesel fuel, fuel combustion – public electricity – emergency generator diesel fuel, industrial processes and product use – refrigerants use, fluorinated gas usage/release). • To support transparency objective, it is *good practice* to request supporting documentation from facility for assessment.

2.3.2.2 COLLABORATION WITH NATIONAL DATA PROVIDERS

Generally, most national datasets represent complete coverage of materials produced or consumed by industries and are developed following accepted methods and this is why many inventory compilers use these datasets as their key activity data inputs to estimate GHG emissions. On the other hand, information obtained from FRP for the same subsector will likely not provide complete coverage of emissions for that subsector as a result of the reporting thresholds, the allowance of a *de minimis*, and differences in sector or source definitions. In most cases,

[27] A quantity of emissions, below which they are not required to be reported. Keeping in mind that it will be necessary for an inventory compiler to estimate the outstanding *de minimis* portion to ensure GHG inventory completeness.

[28] This approach will allow facility to focus efforts on reporting what's essential while reducing their burden to capture for example fuels that are minimally used and contribute less than 1 percent of total GHG emissions.

national dataset can be used to address completeness issues from FRP by calculating the residual value for each industrial classification.

To ensure that emissions are neither over- nor underestimated, collaboration with national data agencies is an essential step in aiding with inventory integration of FRD. Assuming that the information provided to FRP includes activity data (which is fundamental for transparency), it is possible to fill the gaps in facility-reported emissions for a given subsector. This can be done by taking advantage of the linkage between activity data reported to the FRP and those reported to the national data agency. Emissions reported for the portion of the subsector covered by the FRP can be directly used in the inventory, while emissions for the remainder of the subsector can be estimated using the remaining activity data from the national dataset. Techniques for this are discussed in detail below, in order to provide guidance for alignment to be accomplished.

Aligning FRD with national datasets is essential to ensure accuracy and completeness (such as coverage) for related data elements. Working directly with national data organisations can help address issues related to sector allocation and over - or underreporting of consumption or production/feedstock information by industries, with QA/QC performed by participating organisations. This collaborative effort will produce a more consistent dataset for use across all agencies/organisations, increase data collection efficiency and reduce reporting burden (by providing common data requirements at a single point).

To facilitate direct inventory integration of FRD, it is suggested that a working group consisting of experts from the GHG FRPs, GHG inventory compilers, national data compilers (e.g. statistical experts) and other relevant partners work together in establishing common requirements where data needs overlap. This working group should start with identification of common data needs and how best to address gaps and align FRD. This approach will ensure that all required data is collected. At minimum, these common reporting requirements and design element should consider:

- industrial classification system such as Standard Industrial Classification (SIC) or North American Industrial Classification System (NAICS);
- data type and units;
- fuel/feedstock properties – e.g. calorific values, carbon content, moisture content;
- reporting period;
- statistical sample size/weighting adjustment relative to facilities GHG FRP.

Data compilers should compare and review FRP information to identify areas of overlap as this is an opportunity to gain efficiencies and reduce data collection costs. These added savings can be diverted to improve other data deficiencies of participating organisations. These organisations may choose to spend their savings on: increasing the sample size of industries that are not covered by the FRP; increasing survey response rate through improved respondent support; or allow for additional QA/QC and follow up to improve the overall quality and representativeness of the dataset that are not part of the FRP.

Consideration of facility reporting deadlines and survey collection timelines should be coordinated between the FRP, inventory institution and the other data agencies as it is important to have timely data. This will allow for the effective scheduling of processes and quality checks, leading to improved compilations of FRD, GHG inventories and national energy and production datasets.

2.3.3 Approaches for use of facility-reported data

The challenge for inventory compilers is to determine how best to integrate FRD, especially if there are some outstanding completeness issues due to set reporting thresholds. Depending on availability of information and results from quality evaluations, use of FRD may range from simply updating inventory emission factors and activity data to directly integrating the emissions into the inventory. Some examples of integration options, which may be used separately or jointly, are listed below:

- obtain carbon content of key parameters/activity data to develop representative industry or process-specific emission factors (accounting for technology and process efficiencies change over time);
- use improved emission factors to allocate emissions at a more disaggregated industrial level;
- improve trends analysis and assessment by capturing operation changes including technology or process change, fuel switching, production shut down etc;
- direct incorporation of collected activity data;

- direct incorporation of emissions, usually along with the use of corresponding activity data or improved emission factors, and resulting in higher quality estimates and methods.

When an industry provides information to a FRP, its data will include some or all of the emission sources presented in Equation 2.1 depending on its industry classification and what reporting requirements have been established. For example, a pulp and paper facility will likely have energy (fuel combustion), industrial process and waste (e.g. wastewater treatment) sources:

EQUATION 2.1 (NEW)
TOTAL FACILITY EMISSIONS FROM ALL SOURCES

$$E_{Fa} = \left(E_f + E_{fug} + E_p + E_{other_l} + E_{other_m} \right)$$

Where:

E_{Fa} = total reported facility emissions from all sources (excluding the *de minimis*, when applicable)

E_f = sum of all energy (fuel combustion) emissions in the facility

E_{fug} = sum of all fugitive emissions in the facility

E_p = sum of all industrial process emissions in the facility

$E_{other\ l}$, $E_{other\ m}$ = sum of all other emission source type l, m… (e.g. waste, product use, agriculture, etc.)

2.3.3.1 FACILITY-REPORTED DATA INTEGRATION OPTIONS

A rigorous facility-based approach involves using the complete set of data from all facilities for a given industry taking into account all emission sources and their operating conditions. If all quality goals are met and activity datasets are aligned with national datasets including complete coverage, the compiler can directly integrate the reported emission estimates into the inventory. These facility-reported emissions then supplant the former estimates for this industry.

Full coverage, however, is difficult to achieve. It is even less likely that completeness will be assured for an IPCC category (e.g. 1.A.2 "Manufacturing Industries and Construction") rather than at the subcategory level/industrial classification (1.A.2.a "Iron and Steel"). Furthermore, coverage of FRD for a specific industrial classification is only fully complete if no facilities fall below specified thresholds and if there are no significant emissions less than any allowable *de minimis* level (if considered)..[29]

As stated earlier, the main way to ensure completeness under these circumstances is by taking advantage of the linkage between activity data reported to the FRP and the national data agency. This linkage exists because many of the facilities in a subsector would be required to report the same information to both data agency/programme. By identifying these facilities and the industrial classification in which they are categorized (e.g. by NAICS or SIC code), can help establish linkages between the two datasets.

For industrial categories, where reported information provides insufficient coverage, national activity data can be combined with improved emission factors from the FRD to obtain more accurate inventory emission estimates. The industrial categories can be matched using the appropriate industrial classification, while new emission factors for that industry can be applied to the national activity data. Establishing data sharing agreements between data agencies, the FRP, and GHG inventory organisations will allow access to facility-level information, by industrial classification, increasing transparency and usability. To meet confidentiality agreements, data can be presented by total, aggregated industrial categories.

Emission Factor Based Integration

Equation 2.2 is applicable when integrating facility-specific emission factors developed based on reported data. For example, this equation can be used for combustion-based (energy) emissions, fugitive emissions or process specific emissions such as a blast furnace at integrated iron and steel plants. It is *good practice* to document methods, assumptions and approaches used in the development of facility specific emission factors along with FRD quality assessment results.

[29] If that is the case, inventory compilers will need to take into account methods to fill in gaps in completeness.

Equation 2.2 makes use of national activity data for an industrial category to calculate emissions by source or fuel, based on relevant facility-specific information:

EQUATION 2.2 (NEW)
EMISSIONS CALCULATED BY FACILITY-SPECIFIC EMISSION FACTORS

$$E_{IC_s} = \sum_{s=1} \left(AD_{ND_s} \right) \bullet EF_{s-FRD}$$

Where:

E_{ICs} = emissions total for a specific industry classification (*IC*) and IPCC category for source *s* (e.g. fuel consumption quantity by type of fuel, each type of process input, each type of production output quantity)

IC = industrial classification by IPCC and corresponding industrial classification system such as SIC or NAICS

AD_{NDs} = national activity data applicable to source *s* (e.g. fuel consumption quantity by type of fuel) from national dataset by industrial classification

$EF_{s\text{-}FRD}$ = source *s* specific emission factor developed based on FRD

For reference or comparative purposes, the grand total of emissions for a specific industry classification can be calculated by summing all emission sources (e.g. from fuel combustion, fugitive, industrial processes, wastewater, and product use), when coverage and all reporting requirements are complete, as illustrated in Equation 2.1.

General Facility Data Integration

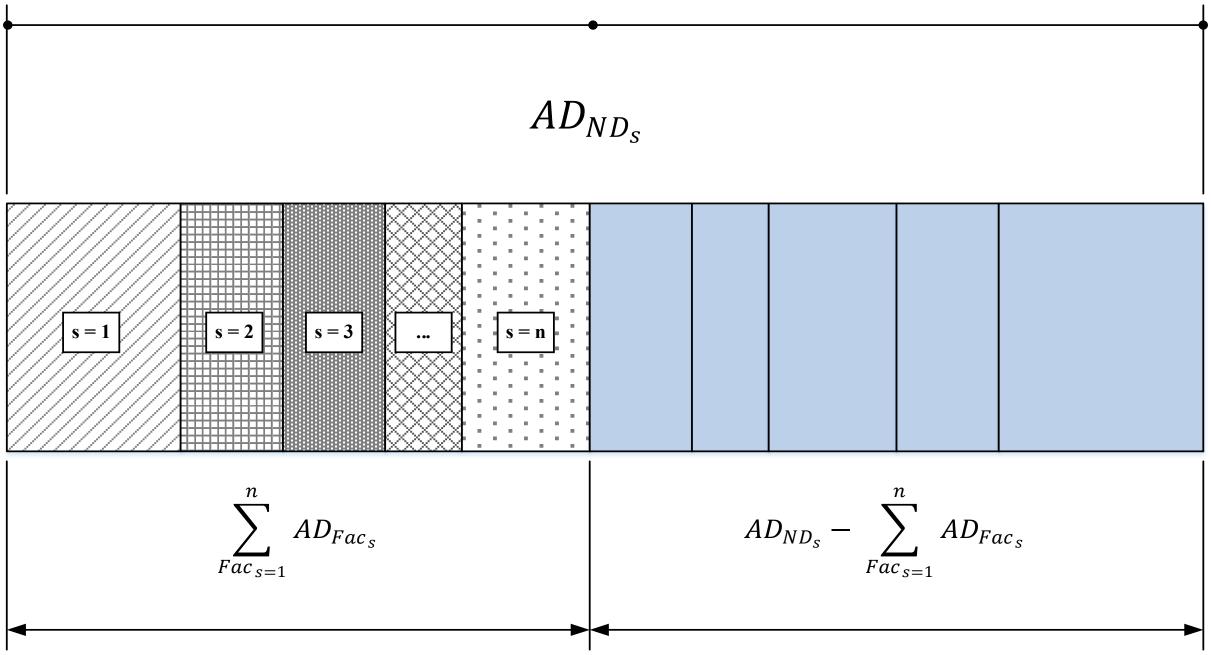
Integration approaches will differ across all inventories due to differences in national circumstances and data availability. The general approach should take into account completeness issues and provides flexibility to compilers in adapting the equation to meet their integration objectives and inventory methods, refer to Equation 2.3 and Figure 2.2. Compilers will also need to reassess integration approaches when reporting requirements are refined and reported information improves over time.

For this approach, it is important to match facility and national activity data where possible by following a standardised industrial classification systems (e.g. NAICS or SIC). As national data agencies generally determine industrial allocations following such classification systems, it would be practical and efficient that emissions reporting facilities be tracked using these same systems to ease alignment of the dataset and incorporation/allocation of the FRD such as emissions by IPCC categorization.

Figure 2.2, is a simple illustration of activity data (e.g. fuel combustion of refinery fuel gas) integration for an industrial classification. This figure demonstrates the relationship between the sum of all FRD ($\sum_{Fac_{s=1}}^{n} AD_{Fac_s}$) and the total national activity dataset (AD_{NDs}) for a specific source, both of which can be utilized when integrating facility emissions into a national inventory. Assuming that the activity data has been reported to the FRP, by identifying what portion of the national activity dataset has been utilized by facilities to estimate their emissions and subtracting that portion of the data from the national activity data, it is possible to calculate the emissions which haven't been reported. The residual value can be demonstrated by the following calculation: $\left[AD_{ND_s} - \sum_{Fac_{s=1}}^{n} AD_{Fac_s} \right]$.

It should be noted that integration process of facility-reported data into national activity dataset could be more complex than illustrated in Figure 2.2. For example, there may be more facilities in one data collection system as compared to another due to differences in reporting requirements, reporting thresholds or methods. It would be productive for all data users and collectors to work together in establishing a data collection system and method to ensure quality data for multiple purposes and to facilitate alignment of data.

Figure 2.2 (New) Illustration of how to integrate FRD into national activity dataset



Total emissions for any industrial classification (for example, emissions from energy and IP for Iron and Steel) can in general be determined as a combination of calculated and facility-reported estimates. This facility data integration equation, Equation 2.3, allows for direct integration of facility-reported emissions (E_{Fas}). In this equation, national activity data is multiplied by facility/industry-based emission factors ($EF_{s\text{-}FRD}$) and added to facility-reported emissions data (E_{Fas}). Applying a facility or industry specific emission factor ($EF_{s\text{-}FRD}$) to the residual value (see calculation above) will address completeness issues due to coverage, *de minimis* or threshold allowances established by the FRP.

EQUATION 2.3 (NEW)
FACILITY DATA INTEGRATION BY EMISSION SOURCE

$$E_{IC_s} = \left(AD_{ND_s} - \sum_{Fac_{s=1}}^{n} AD_{Fac_s} \right) \bullet EF_{s-FRD} + \sum_{Fa_{s=1}}^{n} E_{Fa_s}$$

Where:

E_{ICs} = emissions total for a specific industry classification (IC) and IPCC category for source *s* (e.g. fuel consumption quantity by type of fuel, each type of process input, each type of production output quantity)

IC = industrial classification by IPCC and corresponding industrial classification system such as SIC or NAICS

AD_{NDs} = national activity data from national data provider/agency applicable for source *s* by standard industrial classification systems/IPCC categories

AD_{Facs} = facility-reported activity data applicable to source *s* for a specific standard industrial classification category, equivalent to *n* facilities reporting for a specific industrial classification

$EF_{s\text{-}FRD}$ = facility/industry specific emission factor by source *s,* developed based on FRD corresponding with the activity data for source *s*

E_{Fas} = reported emissions applicable for each source s from each reporting facility, with *n* facilities reporting to FRP for a specific industrial classification

The grand total of emissions for a specific industry and sector classification system (e.g. NAICS or SIC) can be calculated by summing the results of Equation 2.3 for all sources and activities as shown in Equation 2.4.

EQUATION 2.4 (NEW)
TOTAL FACILITY EMISSIONS BY INDUSTRIAL CLASSIFICATION

$$E_{IC} = \sum_{s=1} E_{IC_s}$$

Where:

E_{IC} = emissions total for a specific industry classification by IPCC and corresponding industrial classification system such as SIC or NAICS

E_{ICs} = emissions total for a specific industry classification and IPCC category for source *s* (e.g. fuel combustion, fugitive, industrial processes, etc.)

Note that if no facility data are directly incorporated, Equation 2.3 reduces to Equation 2.2. Furthermore, if only the facility-reported emissions are to be considered, Equation 2.3 reduces to a summary of Equation 2.1.

Depending on the approach to integrate facility data, the amount of information available over time and the level of transparency and quality, there may or may not be a break in the time series consistency. When such break occurs it may be justifiable, such as when a new technology or an alternative energy or fuel has been implemented. In these cases, explanatory documentation should be provided. It is *good practice* to document methods and provide an explanation for the use of facility-reported data, including a discussion on time series consistency, in the inventory. Refer to Volume 1, Chapter 5 of this *2019 Refinement*.

2.3.4 Uses of facility data not originally designed for inventory application

As already noted, facilities data collected primarily for purposes other than for inventory compilation, could still be considered for inventory estimation processes provided an accurate examination of the information collected and the purpose for which it was collected is made.

The available facility data should be assessed on the basis of the following:

- Transparency of the calculation and measurement methods used by the facility.
- Methods and categories of emissions and removals used are in line with IPCC methodologies.
- QA/QC activities have been undertaken and which level of uncertainty is associated with the data.
- Representativeness of the data for the category to be estimated and consistency with national level data (e.g., for combustion emissions: How does the data compare with national energy dataset? For production activities: Is the sample size adequate compared with the number of national production facilities in the IPCC category?).

In fact, these data do not always cover inventory categories entirely whereas national datasets may provide the complete activity dataset required for inventory compilation (e.g. energy categories, such as the national energy balance). Therefore, the first step is to check the coverage of the reported data.

When the sectoral coverage of the category to be estimated is known to be complete, data collected from facilities in the context of different directives and legislation, e.g. emissions trading schemes, can be incorporated into the national inventory (IPCC 2011 [a], [b]).

Under most reporting programmes, industries will provide the required information only if they exceed specific thresholds. More importantly, basic data such as fuel consumption are not supplied and production data are not always split by product but reported as an overall figure. Notwithstanding, the inventory compiler may use these data as a check and take the opportunity to communicate with industries to obtain the additional information necessary to carry out sectoral emission estimates.

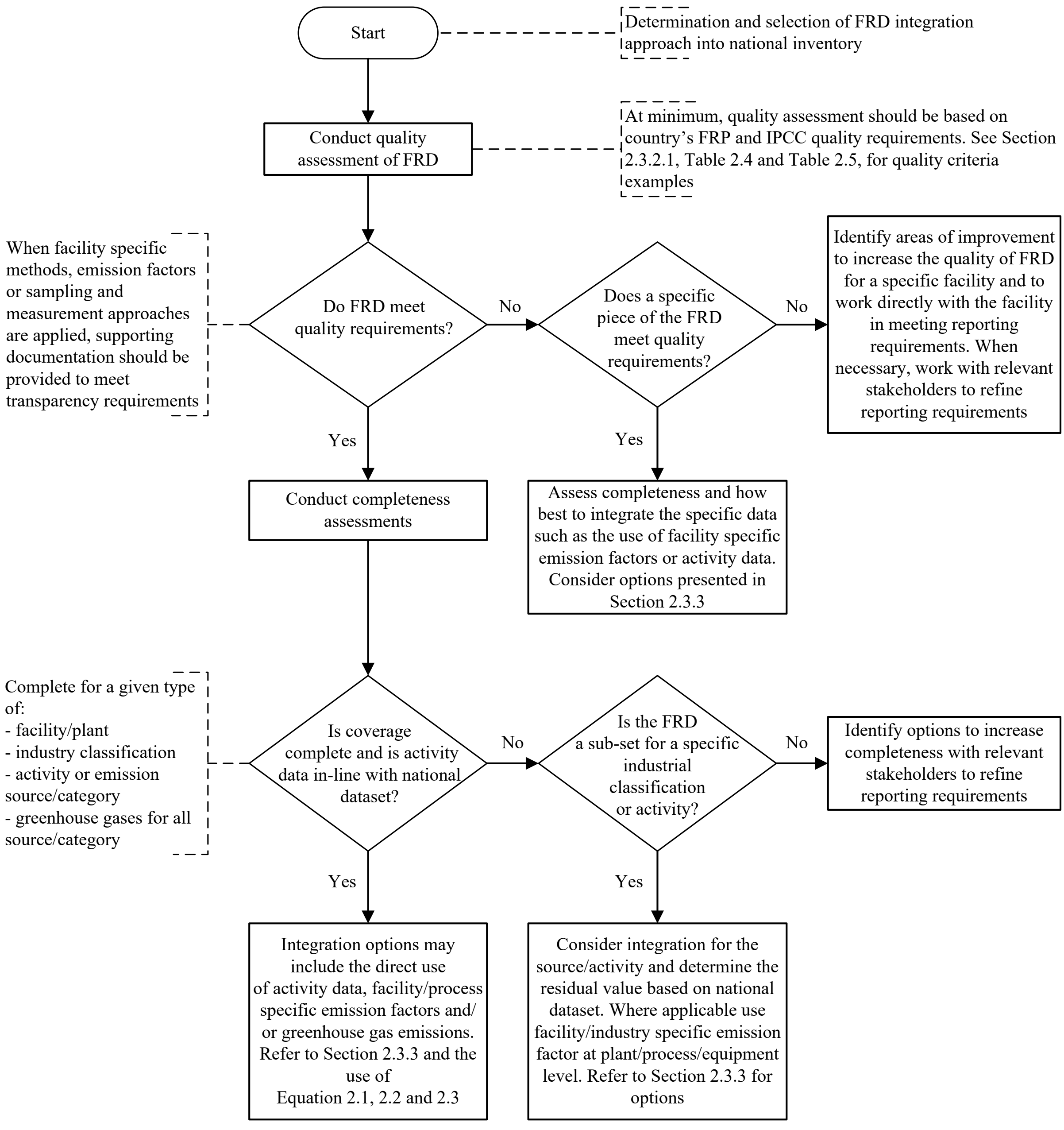
When a category is not completely covered by facility data, an important decision is whether to use the data by integrating them in the emission inventory, and how to complete the emission estimate for the category. Guidance on the use of incomplete coverage of specific data (such as activity data or emissions) is presented in Section 2.3.3.1 Facility-reported data integration options. In addition, even in the case of partial coverage, data may be used:

- To derive country-specific emission factors, or sum up to other activity data.

- To check or compare with inventory emission estimates, emission factors and activity data.
- To derive a proxy measure of data necessary to be used for inventory purposes (e.g. use of facility energy consumption data to split the total emissions into combustion and processes emissions, if the disaggregation is not available). Such a proxy should only be used when it improves the quality of the estimates and follows the appropriate IPCC methods for the source category.
- To fill data gap, with the assumption that reported data is a good representative of the whole population (so the average emission rate of the facility type or industry applies to any missing data within the appropriate context), should do so only when it improves the quality of the estimates and follows the appropriate IPCC methods for the source category.

Figure 2.3 is an example of data quality assessment when considering the use of FRD or data from research studies in national inventories. Decisions and integration processes will vary depending on national circumstances.

Figure 2.3 (New) Sample decision tree for integration of FRD



Another aspect that must be considered is the scenario when facility data will most likely not be available for years prior to the establishment of a FRP and also that methods and parameters from facilities may improve over time. For this reason, inventory compilers will need to pay particular attention to time series consistency by either providing support for the change in trends or developing and documenting a method to address this deficiency (see Chapter 5 of Volume 1, Box 5.2).

Data is sometimes collected only for certain time periods. If data are collected annually, or if the collection occurs only once for a multi-year period, compilers should consider the benefits of its use as a representative of a specific period of time (e.g. for landfills, the collection of data on waste composition may not occur annually, in this case, the composition of waste should be used to represent the composition within those years). Another issue to consider when recalculating data for earlier years is the changes in technology and practices that may have occurred. For further examples and approaches to address time series consistencies, refer to Volume 1, Chapter 5 of this *2019 Refinement*.

Whatever the use of facility data, it is important to provide sufficient data and documentation such that any external reviewer or user of the data can understand how the data has been collected and how it has been incorporated into the GHG inventory for transparency purposes and to facilitate the determination of whether the methods are consistent with IPCC Guidelines.

It is *good practice* for inventory compilers to document and describe the methods applied with regards to facility data integration and the differences between national inventory data and the facility data.[30] Some examples for inclusion into such documentation may be found in the Report of the IPCC Expert Meeting on Use of Models and Measurements in GHG Inventories (IPCC, 2011b).

BOX 2.3 (NEW)
FACILITY DATA CONSIDERATION AND USE

Additional resources for research purposes are available to inventory compilers when considering the use of facility data. These resources, which discuss reporting design considerations, QA/QC checks, implementation and direct usage of facility data, can help compilers in gaining knowledge and assessing how best to use their data.

It is *good practice* to use the following references as starting point:

IPCC (2011b). Use of Models and Facility-Level Data in Greenhouse Gas Inventories (Report of IPCC Expert Meeting on Use of Models and Measurements in Greenhouse Gas Inventories 9-11 August 2010, Sydney, Australia). eds: Eggleston H.S., Srivastava N., Tanabe K., Bassansuren J., Fukuda M., Pub. IGES, Japan 2011.

WRI (2014) Working Paper - Exploring Linkages Between National and Corporate/Facility Greenhouse Gas Inventories, World Resources Institute. N. Singh, T. Damassa, S. Alarcon-Diaz, M. Soto. March 2014.

Compilers may also learn from the experiences of other countries with facility reporting programmes. Examples are the USA, Australia and some European countries, which all have integrated facility data into their national GHG inventories. These countries' national inventory entities all have information on facility reporting requirements and systems.

[30] For example, Article 10 of the European Union Regulation for data consistency is relevant to emissions reported under the European Emissions Trading Scheme. A detailed table with a comparison between reported GHG emissions under UNFCCC and data from the EU ETS by category is included in the National Inventory Reports (NIRs) of many European countries.

References

References copied from the 2006 IPCC Guidelines

Cullen A.C. and Frey H.C. (1999). *The Use of Probabilistic Techniques in Exposure Assessment: A Handbook for Dealing with Variability and Uncertainty in Models and Inputs*. Plenum: New York, 335 pages.

Frey H.C. and Burmaster D.E. (1999). 'Methods for characterizing variability and uncertainty: comparison of bootstrap simulation and likelihood-based approaches,' *Risk Analysis*, 19(1):109-130, February 1999.

Frey H.C. and Rhodes D.S. (1996). 'Characterizing, simulating, and analyzing variability and uncertainty: an illustration of methods using an air toxics emissions example', *Human and Ecological Risk Assessment*: an International Journal, 2(4):762-797, December 1996.

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EEA (2016) EMEP/EEA air pollutant emission inventory guidebook 2016. EEA Report No 21/2016.

IPCC (2011a) Use of Facility-Specific Data in national Greenhouse Gas Inventories. Task Force on National Greenhouse Gas Inventories (TFI). TFI Technical Bulletin 1. Hayama Japan. Accessible at: http://www.ipcc-nggip.iges.or.jp/public/tb/TFI_Technical_Bulletin_1.pdf.

IPCC (2011b) Use of Models and Facility-Level Data in Greenhouse Gas Inventories (Report of IPCC Expert Meeting on Use of Models and Measurements in Greenhouse Gas Inventories 9-11 August 2010, Sydney, Australia). eds: Eggleston H.S., Srivastava N., Tanabe K., Baasansuren J., Fukuda M., Pub. IGES, Japan 2011.

Ogle, S. M., Buendia, L., Butterbach-Bahl, K., Breidt, F. J., Hartman, M., Yagi, K., Nayamuth, R., Spencer, S., Wirth, T. & Smith, P. (2013) Advancing national greenhouse gas inventories for agriculture in developing countries: improving activity data, emission factors and software technology. *Environmental Research Letters* 8(**1**): 8.

Annex 2A.1 A protocol for expert elicitation

No refinement.

Annex 2A.2 General guidance on statistical data and surveys

The collection of information for an inventory use is the most critical and often resource demanding aspect of the process since most inventories rely on data collected for other reasons, especially socio-economic reasons, or such as fuel consumption data that are collected for tax reasons.

In collecting statistical data or performing surveys it is *good practice* for inventory compliance to follow the guidance on QA/QC given in Chapter 6 of this volume.

Survey data are often compiled using financial/fiscal incentives for reporting. This may introduce possible bias if the incentives favour a certain bias in reporting. For example, taxation may encourage under reporting while incentives may encourage over reporting. In addition, differential taxation of different categories using the same fuels may skew reporting, e.g., over-reporting of fuel used in low taxation categories and under reporting of fuels used in high taxation categories. To minimize the cost of new data collection campaigns, collaboration with existing agencies and programs that have an interest in collecting related data from the same subjects should be put in place.

It is clear that the establishment of collection procedures should, over time, improve the quality of the inventory available data sets and consequently emission estimates. The collection of data or parameters should be carried out at a level of detail appropriate to the methods used for each category and the focus starting from the most relevant emission categories - "*key categories*".

As a first step, an inventory compiler should review what data are likely to be available through existing national statistical data system or administrative sources of data should be explored.

Once the collection program is in place, activities should be revised on a regular basis as part of an ongoing improvement of data and inventory quality and the possibility to incorporate new questions or module in the existing questionnaires should be explored. In addition, agreements with data suppliers should guarantee a consistent and continuing information flow.

Where there is no information available at national level, international bodies, such as the United Nations and International Energy Agency, should be considered. In addition, sectoral groups such as international trade and industrial associations may have country-specific data sets for industries or other economic sectors. The list of international organizations with published statistics is provided in Section 2.2.1 of this chapter. Problems with international statistics and their use in the inventory compilation are mainly related to the level of disaggregation reported of parameter/data, their definitions, the use of units of measures and conversion factors used. Therefore, the inventory compiler, when considering international sources, should pay attention to all these factors.

ENERGY SURVEYS

Energy statistics are a fundamental component of emissions inventories and there is great potential for double counting. The best way to avoid double-counting is to compile energy balances according to the basic principles, concepts and methods developed at international level. The United Nations Publication Energy Statistics: A Manual for Developing Countries (UN 1991) serves as a guide for developing countries for the comprehensive, reliable and regular collection of energy statistics. Various sources of inconsistencies, such as sources of data, concepts and definitions and time spans/coverage, are discussed in detail for all types of energy commodities and recommendations are provided to minimise or eliminate them.

The International Recommendations for Energy Statistics (UN 2018a) is a document which describes methods in Energy Statistics, with special reference to Energy Accounts and Balances: the nature of energy statistics and the kinds of policy problems for which they are required; the conceptual and methodological issues to which these problems give rise; and the possible conventions that might be adopted for dealing with some of these issues are included. It also examines the key role played by quantitative overall energy balances; the desirable features of such balances - whether used for analysing the past or for speculating about the future; the classification problems posed by energy statistics; and the relationship between such data and other economic statistics and accounting frameworks.

- Another document published by UN is on definitions, units of measure and conversion factors relative to energy statistics (UN 1987), which contains detailed information on terminologies for energy commodities, units of measurement and conversion from one unit to another. It provides internationally adopted definitions, conversion factors and descriptive tables for analysis and comparison of international energy statistics.

Also, IEA has published an Energy Statistics Manual providing useful background information for collecting, reporting and understanding energy statistics (IEA 2005).

As for energy statistics, there is also a database by the IEA documenting the worldwide energy statistics (IEA 2018).

BP's Statistical Review of World Energy provides a time series of data by country on oil and gas production, consumption and refining, which could be useful for fugitive emissions from this source (BP 2018).

Statistics on the production of hard coal, brown coal, crude oil, natural gas and electricity are collected on a monthly basis by the IEA and are available from the Monthly Bulletin of Statistics Online[31]. Aggregated data on annual production, trade and apparent consumption of primary energy products are also published in the UNSD Statistical Yearbook (UN 2018b). UN Statistical Division is involved with the Asia Pacific Energy Research Centre (APEC), Eurostat, the International Energy Agency (IEA/OECD), the Latin American Energy Organization (OLADE), the Organization of Petroleum Exporting Countries (OPEC) and the International Energy Forum Secretariat (IEFS) in the Joint Organisations Data Initiative (JODI)[32].

Enerdata and Eurostat also provide additional data sets on energy and other statistics[33].

In some cases, energy data are not available at the level of detail necessary to estimate emissions (e.g., for non CO_2 emissions of road transport where the emissions are highly dependent on the use of catalytic converters in petrol vehicles). In these cases, additional survey or census data should be used to make estimates e.g., vehicle sales and traffic survey data.

The International Renewable Energy Agency (IRENA) publishes statistics on renewable energy[34].

Usually not all the information is available from international sources and international questionnaires should be analyzed in order to understand where are the main issues to be solved to improve emission estimates. A discussion among national inventory experts, Ministries of Energy and international organizations and National Statistical Offices should be engaged.

Additional explanations are usually necessary on the type of fuels to understand what specific figures they refer to. In case data are expressed in mass units, attention should be paid to the transformation, for example in energy units (kt to TJ); international data sets may use different calorific values of potential country-specific caloric values and the underlying calorific values used are not always transparent.

In addition, timeliness of the reporting of data should be considered. International organizations may use preliminary data for reporting of recent years, and the updating of historic data are not always applied to international data sets.

Data quality information or uncertainties related to the reported data are not always available. However, the inventory experts should look for the information within the international agency or use default values provided by the IPCC guidelines.

INDUSTRY SURVEYS

Greenhouse gas inventories require data on the production of industrial commodities and, if possible, on the production processes. For the purpose of collecting harmonised statistics on industrial production, standardised commodity lists have been established at international level, and countries are encouraged to adopt these lists for their own purposes, as this will be most cost efficient. These lists are updated regularly to take account of new products being developed. Latest available list based on the Central Product Classification (CPC) and compatible with the International Standard Industrial Classification (ISIC), the European Union’s PRODCOM commodities list and the Harmonised Nomenclature System (HS) used for foreign trade statistics are available on the UN website[35]. Detailed chemical industry data (production per country of many products and process data) can acquired from SRI Consulting (https://ihsmarkit.com/industry/chemical.html): Process data on aluminium

[31] https://www.iea.org/statistics/monthly/.

[32] http://www.jodidata.org/.

[33] https://ec.europa.eu/eurostat/web/energy/overview.

[34] http://www.irena.org/publications.

[35] https://unstats.un.org/unsd/trade/default.asp.

production can be obtained from Aluminium Verlag (http://www.aluverlag.de/); Steel process information can be acquired from IISI (www.worldsteel.com).

It is more difficult to obtain information on production processes used by industry. Business registers may contain this information, but the logistics of keeping this up to date are formidable. Industry associations that bring together businesses working in a common field can often be a useful source of help. As specialists in their field they will have an insider's knowledge of the most common processes used, and may even be willing to survey their members at regular intervals to assess penetration of new processes. In the 1990's Eurostat produced the NOSE-p list – a Nomenclature of Sources of Emissions that links processes to industries. This needs to be revised, but remains a useful starting point for countries starting work in this area.

Data on industrial production and production processes are also extremely useful in producing statistics on industrial waste, see below.

Production data used to estimate emissions from consumption of a product or fuel should, wherever possible incorporate the import/export statistics for that commodity. Production statistics may, with care, be used as a surrogate for consumption when net import or exports are thought to be significant but not quantifiable. However, since there is a possibility of incompleteness or overestimation due to underreporting of imports and/or exports, the completeness of accounting of imports and exports should be checked with the statistical office.

Where production data are used, care should be taken to identify whether the data represents gross or net production (i.e., with or without internal recycling). For some categories these figures could differ by 5 to 10 percent e.g., steel, aluminium and glass. Whatever production statistics are used appropriate emission factors should be applied and the inventory complier should be sensitive to any tax or financial influences that might lead to over or under-reporting of emissions.

Other examples of industry related statistics are the statistics on international trade by the OECD[36] and Eurostat's datasets PRODCOM[37] (production of manufactured goods) and Comext[38] (trade in goods).

In addition, the WTO provides quantitative information in relation to economic and trade policy issues. Its databases and publications provide access to data on trade flows, tariffs, non-tariff measures (NTMs) and trade in value added.

AGRICULTURAL SURVEYS AND CENSUSES

Since its establishment, the Food and Agriculture Organization of the United Nations, (FAO) has promoted national censuses of agriculture through its Programme for the World Census of Agriculture[39]; the Programme is prepared by the Statistics Division of FAO in collaboration with many experienced agricultural statisticians all over the world - see 'Programme for the World Census of Agriculture: 2020'[40].

The Programme is complemented by practical information on the steps involved in actually conducting an agricultural census.

Other guidance from FAO on conducting agricultural surveys includes:

- '*Sampling Methods for Agricultural Surveys*', FAO Statistical Development Series No. 3 (FAO1989a); which presents the foundations of probability sampling theory and the basic concepts involved. It concentrates on sample design, which covers only part of the overall design of agricultural sample surveys. The different sampling methods are discussed, including simple random sampling, stratification, systematic sampling, probability proportional to size sampling, cluster sampling, multi-stage sampling, multi-phase sampling, and area sampling. Also discussed are: sample design issues, such as sample allocation to strata and to different stages of sampling; weighting and sample estimation methods, such as unbiased and ratio estimates; and methods of estimating sampling errors, including replicated methods. Some practical problems involved in designing and conducting sample surveys are also discussed, including frame problems and evaluation of sampling and non-sampling errors.
- *'Collecting Data on Livestock'*, FAO Statistical Development Series No. 4 (FAO 1992a); which presents a general framework for livestock statistics within the context of a national agricultural statistics system.

[36] http://www.oecd.org/trade/.

[37] https://ec.europa.eu/eurostat/web/prodcom/overview.

[38] https://ec.europa.eu/eurostat/web/international-trade-in-goods/overview.

[39] http://www.fao.org/es/ess/census/default.asp.

[40] http://www.fao.org/world-census-agriculture/wcarounds/wca2020/en/.

Different data collection methods are discussed, with particular reference to the problems of nomadic livestock. Guidelines for undertaking livestock censuses are also provided. Concepts and definitions for the collection of data on livestock products (meat, milk, eggs, wool and skins) are presented, along with a discussion of statistics on cost of production and feed/fodder.

- '*Multiple Frame Agricultural Surveys: Volume 1&2'*, FAO Statistical Development Series No. 7 and 10 (1996&1998). National Current Agricultural Survey Programmes, established to obtain reliable and timely baseline data on the agricultural sector, are based on one of three sampling survey methods: list sample designs (commonly farm sampling designs), area sample designs, and multiple frame designs. Multiple frame designs are those which combine an area sample with complementary list (farm) samples. Multiple frame sampling methods should constitute the statistical foundation of the National Agricultural Survey Programmes in a larger range of countries, because of their advantages to the traditional farm sampling methods.

Volume 1 is a comprehensive introduction to establishing and conducting area and multiple frame probability sample survey programmes, with a focus on methods and practices applicable in developing countries. It provides a general classification of alternative agricultural survey designs with an indication of their respective advantages and limitations. It examines several aspects that have to be considered to establish and conduct a periodic agricultural survey programme based on multiple frame sampling methods, i.e., the probability selection and estimation methods, the survey organisation, the equipment and materials needed, data collection, summarisation and processing. The book includes a detailed description of a category of multiple frame survey designs considered especially useful for developing countries.[41]

Volume 2 (FAO 1989b) presents the area and multiple frame survey methods for Agricultural Survey Programmes currently used in a wide range of countries. It provides actual examples of the application of the survey methods presented in the first volume.

FOREST SURVEYS

The FAO is also the lead organisation collecting data on forestry. The Forestry Department of FAO is undertaking important activities of support to national forest monitoring. Forest statistical database[42] provides information on these activities - including on the sampling design, size, plot configuration and variables to collect on the ground.

The FAO has also produced the following relevant publications:

- Knowledge Reference for forest resource assessments (FAO 2015) and Voluntary Guidelines on National Forest Monitoring (FAO 2017); Strengthening National Forest Monitoring Systems for REDD+ (FAO 2018);
- Manual of forest inventory FAO Forestry Paper 27 (FAO 1981);
- Forest volume estimation and yield prediction. FAO Forestry Paper 22/1 (FAO 1980);
- Methods & Guidance Documentation of the Global Forest Observation Initiative (that contains methodological advice for countries wishing to make use of remotely sensed and ground-based data for forest monitoring and reporting)[43];
- Map Accuracy Assessment and Area Estimation. A practical guide (FAO 2016);
- Manual for integrated field data collection (FAO 2012).

Further FAO has developed a set of tools that support data collection for forestry as:

- Collect, survey design and data management tool[44];
- Collect Mobile for data collection and validation in the field[45];
- Calc, a tool for data analysis and results calculation[46];

[41] http://www.fao.org/docrep/009/a0135e/A0135E00.htm.

[42] http://www.fao.org/redd/areas-of-work/national-forest-monitoring-system/en/.

[43] http://www.gfoi.org/methods-guidance/.

[44] http://www.openforis.org/tools/collect.html.

[45] http://www.openforis.org/tools/collect-mobile.html.

[46] http://www.openforis.org/tools/calc.html.

- Collect Earth, a tool for augmented visual interpretation for land monitoring[47];
- System for earth observations, data access, processing & analysis for land monitoring, SEPAL[48].

Free open-source solutions for environmental monitoring provides link to general web site where all tools are available[49].

WASTE SURVEYS

In general, industries will have a good idea of the volume and composition of waste that they produce each year, as they often have to pay to have it removed and appropriately treated. Therefore, surveys to industry should result in reliable data on waste generated and its composition. However, this is such a sensitive area that the response rate is often very low and the data may be unreliable.

Much industrial waste is an unavoidable by-product, the type and volume of which is directly proportional to the volume of production, and will depend on the technology used in the production process. Therefore, for each technology type, a waste factor can be produced. Much of the available statistics on industrial waste are the results of models based on these factors together with information on industrial production and the distribution of the main technological processes used in the industry being assessed. A useful source for this is the European Environment Agency's report 'Development and application of waste factors: an overview (EEA 1999) which provides an overview of waste factors, their derivation and application and experiences in using them, based on reports and available literature. For municipal waste, direct surveys are not the best way to estimate volumes or composition. Their main disadvantage is that they are costly and the respondents often have little idea of the real volume of waste they generate, nor of its composition, resulting in large uncertainties in the resulting figures.

The most common estimation method for municipal waste is simply to weigh a sample of the waste collection vehicles before and after collection, and to gross up to cover the whole population. The sample will need to cover vehicles collecting in a wide range of areas: urban and rural, wealthy and poor, with and without gardens, etc. and covering several periods throughout the year, so that the sample can be seen as representative for the whole population and the whole year. Estimation of the composition of municipal waste is more complicated. Panels of households can be set up to monitor their waste generation and composition more closely and over time. Panels are basically small samples that remain constant over time, and therefore are well suited to monitor trends. Because the panel will need to be very actively involved in weighing and analyzing the contents of their waste bins, it is often necessary to pay the participants for their input, and this can be a serious limiting factor. Therefore, factors for composition are often based on research projects and technical studies carried out in research institutes, sometimes but not always at the request of the relevant municipality or ministry.

In other cases, e.g. for landfills, the amount of waste disposed of in controlled landfills should be monitored together with the amount of population or area served. Therefore, the amount of waste generated per inhabitant could be approximately derived. In addition, some information on the amount of waste disposed of in uncontrolled landfills could be available. For incinerators, which capacity is usually known, the same method could be applied.

International waste statistics may be found in Eurostat's website[50] where data are provided by the national statistical authorities. Other statistics on international waste are generated by different sources:

- European Environmental Agency[51];
- Organization for Economic Co-operation and Development (OECD)[52];
- The United Nations[53];
- The World Bank[54].

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[47] http://www.openforis.org/tools/collect-earth.html.

[48] http://www.openforis.org/tools/sepal.html.

[49] http://www.openforis.org/.

[50] https://ec.europa.eu/eurostat/web/waste/overview.

[51] https://www.eea.europa.eu/data-and-maps/data/external/generation-of-waste-statistics.

[52] https://data.oecd.org/waste/municipal-waste.htm.

[53] https://unstats.un.org/unsd/environment/wastetreatment.htm.

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