FAQs

Frequently Asked Questions

1. IPCC Task Force on National Greenhouse Gas Inventories (TFI), general guidance and other inventory issues

1.1. Questions about IPCC National Greenhouse Gas Inventories Programme

Q1-1-1. What is the role of the IPCC in Greenhouse Gas Inventories and reporting to the UNFCCC?

A: The IPCC has generated a number of methodology reports on national greenhouse gas inventories with a view to providing internationally acceptable inventory methodologies. These methodology reports are available on the following website http://www.ipcc-nggip.iges.or.jp/public/. The IPCC accepts the responsibility to provide scientific and technical advice on specific questions related to those inventory methods and practices that are contained in these reports, or at the request of the UNFCCC in accordance with established IPCC procedures. The IPCC has set up the Task Force on National Greenhouse Gas Inventories (TFI) to run the National Greenhouse Gas Inventory Programme (NGGIP) to produce this methodological advice. Parties to the UNFCCC have agreed to use the *IPCC Guidelines* in reporting to the Convention. Annex I Parties shall use the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (*2006 IPCC Guidelines*) and are encouraged to use the 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (*Wetlands Supplement*).

For the purpose of providing information on anthropogenic greenhouse gas emissions and removals from LULUCF activities under Article 3, paragraphs 3 and 4 of the Kyoto Protocol, Annex I Parties shall apply, as appropriate, the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (*KP Supplement*). The *Wetlands Supplement* shall apply for providing information on wetland drainage and rewetting elected activity under Article 3.4 of the Kyoto Protocol and is encouraged but not mandatory for any other activities under Article 3.3 and 3.4 of the Kyoto Protocol.

Non-Annex I Parties should use the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (*Revised 1996 IPCC Guidelines*)*,* Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (*GPG2000*), and the Good Practice Guidance for Land Use, Land-Use Change and Forestry (*GPG-LULUCF*). Some non-Annex I Parties have started using also the 2006 IPCC Guidelines in their reporting to the UNFCCC.

In addition, Paris Agreement (Article 13 paragraph 7(a)) states that Each Party shall regularly provide a national inventory report of anthropogenic emissions by sources and removals by sinks of greenhouse gases, prepared using good practice methodologies accepted by the IPCC and agreed upon by the Conference of the Parties serving as the meeting of the Parties to this Agreement.

Q1-1-2. How does the IPCC produce its Inventory Guidelines?

A: Utilising IPCC procedures, nominated experts from around the world draft the reports that are then extensively reviewed twice before approval by the IPCC. This process ensures that the widest possible range of views are incorporated into the documents. See http://www.ipcc-nggip.iges.or.jp/ for full details.

Q1-1-3. What are the required steps to be taken to have an inventory methodology accepted by the IPCC?

A: The IPCC NGGIP follows IPCC procedures and inventory methodology reports are prepared in accordance with the decision of the IPCC. When preparing inventory methodological reports, authors review the latest science and technological knowledge for the best methodologies. These are then described in the methodology report which is reviewed once by experts and the second time by governments and experts before adoption/acceptance by the IPCC.

It should be noted that the IPCC does not limit specific methodologies to be used, but rather where a better national method is available for a specific sector the IPCC recommends it be used. The only requirement is that these national methods should be transparent and documented.

Q1-1-4. How can new data and information be taken up by the IPCC NGGIP?

A: The IPCC NGGIP can only include in its reports the new inventory information that are approved by the IPCC process. The IPCC NGGIP follows IPCC procedures and inventory methodology reports are prepared in accordance with the decision of the IPCC. However the IPCC has created the Emission Factor Database (EFDB). This aims to be a constantly updated library of emission factors and other parameters that can be used by inventory compilers under their responsibility. New data and parameters can be proposed to the EFDB for dissemination on a wider basis. The Editorial Board of the EFDB examines such proposals in terms of their scientific robustness. See http://www.ipcc-nggip.iges.or.jp/EFDB/ for full details.

1.2. Questions about general issues on national GHG inventories and IPCC Guidelines

Q1-2-1. How do greenhouse gases affect the atmosphere?

A: Scientific aspects of greenhouse gases are dealt with by Working Group 1 of the IPCC. See http://www.ipcc.ch/.

Q1-2-2. What are the major greenhouse gases?

A: Scientific aspects of greenhouse gases are dealt with by Working Group 1 of the IPCC. See http://www.ipcc.ch/. The NGGIP deals with the following anthropogenic emissions by sources and removals by sinks of greenhouse gases (GHG).

Those covered in the *Revised 1996 Guidelines*;

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFCs - this is really a family of gases, there are many individual gases)
- Perfluorocarbons (PFCs - this is also a family of gases)
- Sulphur hexafluoride (SF_6)

Other direct GHG covered in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (*2006 Guidelines*);

- Nitrogen trifluoride (NF_3)
- Trifluoromethyl sulphur pentafluoride (SF_5CF_3)
- Halogenated ethers

- Other halocarbons

The NGGIP inventory guidelines do not include gases covered by the Montreal Protocol, such as;

- Chlorofluorocarbons (CFCs - this is also a family of gases)
- Hydrochlorofluorocarbons (HCFCs - this is also a family of gases)

There are also the “indirect” GHGs that do not directly contribute to the greenhouse effect, but once they are released into the atmosphere they form substances (e.g. tropospheric ozone O_3, aerosols) which contribute to the greenhouse effect. Indirect anthropogenic greenhouse gases are, amongst others, carbon monoxide (CO), non-methane volatile organic compounds (NMVOC), nitrogen oxides (NO_x), ammonia (NH_3) and sulphur dioxide (SO_2). *2006 Guidelines* contain links to information on methods used under other agreements and conventions, for the estimation of emissions of tropospheric precursors which may be used to supplement the reporting of emissions and removals of greenhouse gases for which methods are provided.

Q1-2-3. Why is water vapour not covered by the *IPCC Guidelines*?

A: There is a natural greenhouse effect which is largely driven by water vapour (H_2O) and other greenhouse gases which occur to a certain extent naturally in the atmosphere. However anthropogenic emissions of water vapour do not contribute significantly to the change of atmospheric water vapour concentration. Thus, the *IPCC Guidelines* do not deal with water vapour as an anthropogenic GHG.

Q1-2-4. How can you compare emissions of different gases?

A: The radiative impact of a single GHG depends on the amount emitted and its specific properties. Currently, in reporting to the UNFCCC, Parties are asked to weigh their emissions by the “Global Warming Potential” (GWP). The GWP are calculated as the ratio of the radiative forcing of one kilogramme greenhouse gas emitted to the atmosphere to that from one kilogramme CO_2 over a period of time. The precise numbers to be used are laid down by the UNFCCC and at present they are for a 100 year time horizon. (Also see Q1-2-11.) (See the Working Group 1 reports <http://www.ipcc.ch/>).

Q1-2-5. Is reporting of GHG limited to six gases?

A: Decisions on what gases to report are made by the Parties to UNFCCC or to the Kyoto Protocol, not the IPCC. (See detailed reporting requirements: http://unfccc.int.)

Q1-2-6. What are precursor gases? Do we need to estimate for these for inclusion in the GHG inventory of the AFOLU Sector?

A: Precursors are gases whose emissions lead to the formation of substances in the atmosphere with a climate change impact. Precursors include SO_2, NO_x, NMVOC and CO. Precursor gases are known as such because they are precursors to the formation of greenhouse gases in the atmosphere. For a complete estimation of emissions from the AFOLU Sector, emissions of gases which give rise to indirect N_2O (i.e. NO_x and NH_3) need to be estimated. Indirect N_2O emissions are dealt with in Section 4.8, Chapter 4, of *GPG2000* and Section 11.2.2, Chapter 11, Volume 4(2) of *2006 Guidelines*.

Q1-2-7. Are national methods, if available, considered to be better than those presented in the *IPCC Guidelines* (e.g., "default" methods)? If yes, where can we find in the *IPCC Guidelines* such statements?

A: YES, if it is well documented, better represents the national circumstances than the IPCC default methods and produces comparable and consistent results for each year in the time series.

See the *Revised 1996 Guidelines*, Vol.1 Reporting Instructions, Page Introd.2, Page Overview.4, and Page Overview.6.

Q1-2-8. Why do the sectoral definitions used by the IPCC for emission calculations differ from those used elsewhere e.g. used by NAMEA (national accounting matrix including environmental accounts) for emissions?

A: The *IPCC Guidelines for National Greenhouse Gas Inventories* aim to estimate total annual NATIONAL emissions. Hence the inventories aim to estimate all the emissions from the area under national jurisdiction for a specific year. The definitions follow this with a few pragmatic deviations and are designed to be globally applicable.

Inventories developed for different purposes may have different definitions, for example:

- They may consider extra-territorial emissions. For UNFCCC reporting, emissions from international bunker fuels are not included in national total emissions. The IPCC considers emissions under the jurisdiction of a country. For example, emissions from international bunker fuel use are not included in national total emissions.
- There may be a greater focus on economic considerations and the need for linkage to economic data.
- Differences may have developed historically. For example some local inventories have been developed to meet local needs.

Q1-2-9. In the IPCC Guidelines, is ‘NO_x’ assumed to be NO_2 or NO, or some combination of NO and NO_2?

A: The convention in the *Revised 1996 IPCC Guidelines* and the *2006 Guidelines* is that NO_x (NO + NO_2) emissions are expressed on a full molecular basis assuming that all NO_x emissions are emitted as NO_2. (See the footnote on Page 1.37 of Vol.3 of the *Revised 1996 Guidelines*.)

Q1-2-10. Should I include emissions from sources not discussed in the *IPCC Guidelines*?

A: To be complete all significant sources of emission should be included. Where there is a source that is not included in the *IPCC Guidelines* it should still be reported where possible. Sources may not be included in the guidelines because there is not enough information to develop globally applicable methods or because they are specific to one or a few countries.

Q1-2-11. Differing Global Warming Potential (GWP) values are presented in the IPCC SAR, TAR, AR4 and AR5. Which values should be used in calculation of GHG emissions in tonnes of CO_2-equivalent?

A: The IPCC Working Group I (WGI) presents GWP values based on the up-to-date science, but does not recommend any rules on application of those values. The IPCC WGI also presents Global Temperature change Potential (GTP) values in its contribution to the "Fifth Assessment Report (AR5)" which was published in 2013. (See IPCC WGI contribution to the AR5 "Climate Change 2013: The Physical Science Basis" (http://www.ipcc.ch/).
As science develops over time, the IPCC has conducted periodic assessments on human induced climate change, and the latest assessment resulted in the AR5.

It is not the role of the IPCC TFI to make any recommendation on which CO_2 equivalent factors such as GWP and GTP values should be applied. For the purpose of official submissions of national GHG inventories under the UNFCCC, the Kyoto Protocol and the Paris Agreement, see the UNFCCC website (https://unfccc.int/process-and-meetings/transparency-and-reporting/methods-for-climate-change-transparency/common-metrics).

Q1-2-12. What is a conservative estimate of emissions/removals? Do the IPCC Guidelines provide methodological guidance for conservative estimates?

A: The IPCC Guidelines do not provide methodological guidance for conservative estimates. According to the IPCC Guidelines, inventories consistent with good practice are those which *contain neither over- nor under-estimates so far as can be judged, and in which uncertainties are reduced as far as practicable.* This means that the IPCC Guidelines are intended to provide guidance for developing inventory estimates that are accurate, but not conservative.

Conservativeness aims at minimizing the environmental risk of under-estimation or in some cases (e.g. base year estimates) over-estimation for specific accounting applications. For example:

- Under the Kyoto Protocol, in the case that expert review teams cannot agree with national estimates, an adjustment procedure applied to a Party's national GHG inventory according to the Article 5.2 shall result in estimates that are conservative for the Party concerned so as to ensure that anthropogenic emissions are not underestimated and anthropogenic removals by sinks and anthropogenic base year emissions are not overestimated.
- For a CDM project activity which is not afforestation or reforestation, the establishment of a baseline is considered conservative if the resulting projection of the baseline does not lead to an overestimation of GHG emission reductions attributable to the CDM project activity
.

The rules for producing these conservative estimates are sometimes derived from consideration of IPCC uncertainty ranges.

Q1-2-13. What is good practice and where we can find good practice guidance in the IPCC Guidelines?

A: Inventories consistent with good practice are those which contain neither over- nor under-estimates so far as can be judged, and in which uncertainties are reduced as far as practicable. Good practice also entails producing inventories that are transparent, complete, consistent, comparable and accurate, and IPCC provides cross-cutting guidance on achieving these characteristics. The concept was defined and elaborated in the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (GPG 2000) via a collection of methodological principles, actions and procedures, and then retained in the 2006 IPCC Guidelines. Good Practice has achieved general acceptance amongst countries as the basis for inventory development. Volume 1 (General Guidance and Reporting) of the 2006 IPCC Guidelines provides good practice guidance on issues that are common to all the estimation methods covered by the sector-specific guidance provided in Volumes 2 to 5.

Q1-2-14. What is time series consistency of emissions/removals estimates and where I can find guidance in the IPCC Guidelines?

A: A time series is a central component of the GHG inventory. It provides information on emissions trends (e.g., annually from a base year to the most recent year) and tracks changes in emissions over the period covered. In order to reflect real changes in emissions/removals, all estimates in a time series should be estimated consistently, which means that as far as possible and appropriate, the time series should be calculated using the same method and data sources in all years. Developing a consistent time series is essential for establishing confidence in reported inventory trends. Chapter 5 (Time Series Consistency) of Volume1 of the 2006 IPCC Guidelines provides methods for ensuring time-series consistency. This chapter also provides good practice guidance on when to recalculate estimates for previous years and methods for tracking changes in emissions and removals over time.

Q1-2-15. Where we can find in the IPCC Guidelines guidance on how to deal with confidential data/information when preparing inventories?

A: Chapter 2 (Approaches to Data Collection) of Volume1 of the 2006 IPCC Guidelines provides guidance on how to use restricted data in compiling inventories while ensuring both confidentiality and methodological transparency.

Q1-2-16. Is there a quick guide to the 2006 IPCC Guidelines?

A: The Overview Chapter and Chapter 1 of Volume 1 of the *2006 IPCC Guidelines* serve as a quick guide. The Overview Chapter (http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/0_Overview/V0_1_Overview.pdf) broadly describes the background, structure and major features of the *2006 IPCC Guidelines*. Chapter 1 of Volume 1 (http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_1_Ch1_Introduction.pdf) provides an introduction to the *2006 IPCC Guidelines* for a broad range of users, including countries and inventory compilers setting out to prepare inventory estimates for the first time.
In addition, a primer to the *2006 IPCC Guidelines*, available at TFI website (http://www.ipcc-nggip.iges.or.jp/support/support.html), introduces the *2006 IPCC Guidelines*, summarises the basic approach for inventory development, and provides guidance on their use. The primer helps the reader to understand the *2006 IPCC Guidelines*, but is not on its own IPCC guidance.

1.3. Questions about uncertainties

Q1-3-1. How do we understand "uncertainty" in emission inventories? How to distinguish between variability and uncertainty?

A: ***Uncertainty:*** Lack of knowledge of the true value of a variable. Uncertainty comprises two parts:

- Random variation around a mean value. Generally these can be quantified and the IPCC guidelines give methods deal with the random errors.
- Bias cannot be quantified and so the IPCC guidelines give approaches to minimise bias.

Uncertainty depends on the analyst's state of knowledge, which in turn depends on the quality and quantity of applicable data as well as knowledge of underlying processes and inference methods. Uncertainty may arise for an inability to quantify the variable. For example, soil nitrous oxide emissions can vary from year to year due to weather conditions, and if emission factors do not account for weather, then some of the uncertainty will be due to variability in emissions across time (and space) that is not quantified.

Variability: How a variable differs from time to time, place to place or between members of a population. A number of source categories, mainly in the AFOLU sector may show temporal variability on long time scales, due to for instance wild fires, rain fall, temperatures etc.

> ***Uncertainty****: Lack of knowledge of the true value of a variable that can be described as a probability density function (PDF) characterising the range and likelihood of possible values. Uncertainty depends on the analyst's state of knowledge, which in*

turn depends on the quality and quantity of applicable data as well as knowledge of underlying processes and inference methods.

***Variability**: Heterogeneity of a variable over time, space or members of a population (...). Variability may arise, for example, due to differences in design from one emitter to another (inter-plant or spatial variability) and in operating conditions from one time to another at a given emitter (intra-plant variability). Variability is an inherent property of the system or of nature, and not of the analyst.*

IPCC 2006, Vol. 1, Ch 3, Section 3.1.3 Key concepts and terminology

Q1-3-2. What is the difference between accuracy and precision? Does uncertainty assessment relate to both?

A: Essentially **accuracy** is a measure of the lack of bias of an estimate while **precision** is a measure of the repeatability of the result. In general lack of precision is caused by random variation in input data (e.g. experimental error) while lack of accuracy results from biases from incomplete understanding (or modelling) of the process. So, for example:

- Estimates of CO2 emissions from fuel use can be based on measurements of the carbon content of the fuel. Reductions in the random error in the measurements will lead to improvements in the precision of the result; however the accuracy may be limited by a bias caused by an incomplete knowledge of the oxidation rate of the combustion process.
- Emissions or removals from forests are modelled by changes in carbon stocks. The precision achieved will be the result of the uncertainty derived from the experimental error of the measured values of the various parameters used. On the other hand, there may be inaccuracy caused by such things as the measured parameters not being measured under the same climatic and ecological situation as the forest area being estimated; by an incomplete knowledge of all the processes removing carbon from the forest; or by the model of carbon stocks being incomplete. All these causes of inaccuracy lead to bias.
- Emissions of F-gases for refrigeration are estimated from monitoring the imports, exports, production and use of the chemicals. Data on these product flows often come from surveys, all of which are subject to random survey errors, which lead to a lack of precision. While biases in the surveys (e.g. caused by missing some sectors) or incorrect understanding of leakage processes lead to inaccuracy and bias.

The process of uncertainty estimation aims to quantify precision. Before this uncertainty estimation is performed all known or suspected biases should be removed or corrected.

Accuracy is improved by evaluating methods and assumptions as well as input data to ensure they are free from bias.

*"**Accuracy**: Agreement between the true value and the average of repeated measured observations or estimates of a variable. An accurate measurement or prediction lacks bias or, equivalently, systematic error.*

***Precision**: Agreement among repeated measurements of the same variable. Better precision means less random error. Precision is independent of accuracy".*

IPCC 2006, Vol. 1, Ch 3, Section 3.1.3 Key concepts and terminology

"The quantitative uncertainty analysis tends to deal primarily with random errors based on the inherent variability of a system and the finite sample size of available data, random components of measurement error, or inferences regarding the random component of uncertainty obtained from expert judgement. In contrast, systematic errors that may arise because of imperfections in conceptualisation, models, measurement techniques, or other systems for recording or making inferences from data, can be much more difficult to quantify. As mentioned in Section 3.5, Reporting and Documentation, it is good practice for potential sources of uncertainty that have not been quantified to be described, particularly with respect to conceptualisation, models, and data and to make every effort to quantify them in the future.
Good practice requires that bias in conceptualisations, models, and inputs to models be prevented wherever possible, such as by using appropriate QA/QC procedures. Where biases cannot be prevented, it is good practice to identify and correct them when developing a mean estimate of the inventory. In particular, the point estimate that is used for reporting the inventory should be free of biases as much as it is practical and possible. Once biases are corrected to the extent possible, the uncertainty analysis can then focus on quantification of the random errors with respect to the mean estimate".

IPCC 2006, Vol. 1, Ch 3, Section 3.1.4 Basis for uncertainty analysis

Q1-3-3. How would uncertainty in activity data and/or emission factors be reflected in the emission estimate?

A: Where uncertainty in emission factors and activity data arise from random factors (e.g. experimental error, survey errors) then this will lead to a quantifiable uncertainty in the result. However if this uncertainty is systematic (e.g. where emission factors are estimated from a sub-population and so are not directly applicable to the entire population; or where a survey does not randomly sample the entire population, e.g. it misses small plant) it might lead to bias. Random errors are expressed as an uncertainty range. Bias should be minimised by thorough evaluation of the data and assumptions used, good QA/QC and review. In some cases, it is possible to correct for biases such as errors in measurements or analytical methods where the error has been quantified and can be used to adjust the estimates.

Q1-3-4. Why uncertainty assessment is considered important in GHG inventory preparation? How should the result of uncertainty assessment be used?

A: Uncertainty assessment is needed to help guide inventory improvements.

"An uncertainty analysis should be seen, first and foremost, as a means to help prioritise national efforts to reduce the uncertainty of inventories in the future, and guide decisions on methodological choice. For this reason, the methods used to attribute uncertainty values must be practical, scientifically defensible, robust enough to be applicable to a range of categories of emissions by source and removals by sinks, methods and national circumstances, and presented in ways comprehensible to inventory users."

IPCC 2006, Vol.1, Ch 3, Section 3.1.1 Overview of uncertainty analysis

"… Uncertainty information is not intended to dispute the validity of the inventory estimates, but to help prioritise efforts to improve the accuracy of inventories in the future and guide decisions on methodological choice, …"

IPCC 2000, Ch 6, Section 6.1 Overview

Uncertainty information is used principally to identify planned improvements in emission inventories.Uncertainty assessment is also important in comparisons with atmospheric measurements and modelling. Without uncertainty estimates, it is difficult to determine the extent to which atmospheric measurements (such as atmospheric inversions of CO_2 concentrations) can be compared to emission estimates. Uncertainty of estimates or measurements may also assist in informing decisions about efforts to mitigate emissions.

Q1-3-5. Can we reduce uncertainties by using higher tier methods to estimate GHG emissions/removals? Sometimes higher tier methods result in wider confidence interval. How should this be interpreted?

A: Moving to a higher tier method should result in a better estimate with reduced uncertainty. However note that:
Sometimes the higher tier method better estimates uncertainty revealing the Tier 1 result underestimated the true uncertainty.
Using higher tiers aims to reduce bias (e.g. it uses more disaggregated data to move to a more detailed stratification) but this can sometimes decrease precision, giving a higher uncertainly value.

"Choice of methodological tier for emissions and removals estimation can affect the uncertainty analysis in two different ways. Firstly, moving to higher tier inventory methods should typically reduce uncertainties, provided the higher tier methods are well implemented, because they should reduce bias and better represent the complexity of the system. Secondly, moving to higher tier methods may result in increased estimates of uncertainty in some circumstances. Often, this increase in the estimated uncertainty does not actually represent a decrease in knowledge; rather, it typically reveals a more realistic acknowledgment of the limitations of existing knowledge. This may occur where there was an incomplete accounting of the greenhouse gas emissions in the lower tier method, or where application of higher tier methods reveals additional complexity and uncertainties that were not fully apparent in the lower tier method. This really means that the uncertainty was underestimated previously and moving to the higher tier method in reality produces a more accurate estimate of uncertainty. In some cases, an increase in uncertainty may occur for one inventory development method versus another because each method has different data requirements."

IPCC 2006, Vol. 1, Ch 3, Section 3.1.7, Implications of methodological choice

Q1-3-6. Can we compare uncertainty estimates between counties?

A: Yes – the numbers should be comparable if both countries have followed the guidelines correctly. While Approach 2 should give a quantitatively better estimate of the confidence limits Approach 2 and Approach 1 give comparable results especially with respect to ranking the contributions to overall inventory uncertainty. Large differences in inventory uncertainties should reflect real differences in the uncertainties of the estimates. However, in practice, there are wide differences between the results that are not easily explained.
An inventory with a high uncertainty may result from a preponderance of sources with intrinsically high uncertainties (e.g. land use sectors) or from a lack of knowledge of the input data more generally. High uncertainty at the national, annual level is often the result of large variability (see Q1-3-6.).

Q1-3-7. How can we ensure consistency in uncertainty assessment among different sectors?

A: There is a need to ensure correct application of guidelines on uncertainty across sectors and source categories. All the inventory compilers for different sectors in the team should have close consultation and discussion so that they arrive at common understanding of "uncertainty". The uncertainty estimation should be explicitly included within the inventory planning process, based on a common understanding of uncertainty, and using similar definitions and ways to quantify uncertainty across sectors and source categories.

Q1-3-8. How do you start an uncertainty assessment?

A:

a Decide on approach to use (look at expertise and resources available)

b Collect uncertainty information for all data inputs. Where Approach 2 is used full probability density function (PDF) will be needed for activity data, emission factors and any other parameters used. If a full PDF is not available a normal or lognormal PDF can be based on the mean and uncertainty. Knowledge of the causes of uncertainty will inform this step.

c Decide how to aggregate sources and sinks to minimise impact of correlations (or for Monte-Carlo develop method to incorporate correlations in activity data and emission factors)

d Combine uncertainty information to estimate overall inventory uncertainty either using error propagation or Monte-Carlo methods as decided in step "a"

e Report result and document method

f Use uncertainly information in developing improvement plan for inventory

Q1-3-9. How should the data and information on uncertainty be collected?

A: Uncertainty information should be collected together with activity and emission factor data. Generally the experts providing both types of data have the best information and knowledge on the weaknesses and uncertainties in their data. Communication on understanding of uncertainties and the objectives of the uncertainty assessment with the data providers is crucial. In some cases data providers might be reluctant to provide uncertainty data. In such cases the inventory compiler could use a formal or informal "expert elicitation" process to help the experts to quantify their understanding of the quality of the data in terms of uncertainty ranges and/or PDFs.
As a fall back option when no data have been included by the data providers, the default uncertainty ranges given in the 2006 IPCC Guidelines could be used for a first uncertainty assessment. If these source categories appear to have major contributions to the overall inventory uncertainty, further work on these uncertainties could be planned for next inventory cycles.

"…Ideally, the inventory compiler should collect activity data, emission factors, and uncertainty information at the same time because this is the most efficient strategy."

IPCC 2006, Vol. 1, Ch 1 p 1.11, Box 1.1

."… Activity data are often collected and published regularly by national statistical agencies, which may have already assessed the uncertainties associated with their data as part of their data collection procedures. These previously developed uncertainty estimates can be used to construct PDFs. This information will not necessarily have been published, so it is recommended to contact the statistical agencies directly. Since economic activity data are not usually collected for the purpose of estimating greenhouse gas emissions and removals, it is good practice to assess the applicability of the uncertainty estimates before using them."

IPCC 2006, Vol. 1, Ch 3, p 3.18

Anytime you have a survey or a census you must have a point estimate and an uncertainty interval. Surveys need a valid statistical design so that variances and co-variances can be empirically derived. Surveys may use stratification to sample more efficiently. Samples should be randomized within the strata. Weights may also be needed depending on the representativeness of each sample. An example of a statistically-based survey is the US National Resources Inventory. In order to start collecting such uncertainty data:

- Consult with your statistical agencies to collect this data
- Always ask for point estimates and uncertainty data, if necessary ask for uncertainty information in a second step
- If you don't get it: use your own expert judgment as a start; you can always improve in the next inventory cycle!
- As a start you can use information in the 2006 Guidelines and EFDB
- Make comparisons with other datasets and other countries. An example of collection of uncertainty information can be a comparison of two databases e.g. If in a country fuel consumption is recorded in energy balance and in parallel of CLRTAP emissions database
- Be aware that experts might be optimistic/subjective with respect to the quality of their data

Q1-3-10. How should we choose the approach to uncertainty assessment, Approach 1 or Approach 2? Can we use both approaches in the same GHG inventory?

A: You will always need to consider the resources and expertise available. Approach 1 requires fewer resources and limited expertise compared with Approach 2.

Approach 1 will usually be good enough if you only use uncertainty for inventory improvement. Approach 2 will be more appropriate for scientific applications where there are high uncertainty ranges and correlations.

Approach 2 can be nested in an Approach 1 for the overall inventory uncertainty assessment. Approach 2 can for instance be used for specific complex calculations in restricted source or sink categories. The resulting uncertainty range for this source or sink then can be used as input into Approach 1 to combine these results with the entire inventory.

Where Approach 2 is used the guidelines also encourage the use of Approach 1 as a QA/QC check.

> *"Where the conditions for applicability are met (relatively low uncertainty, no correlation between sources except those dealt with explicitly by Approach 1), Approach 1 and Approach 2 will give identical results. However, and perhaps paradoxically, these conditions are most likely to be satisfied where Tier 2 and Tier 3 methods are widely used and properly applied in the inventory, because these methods should give the most accurate and perhaps also the most precise results. There is therefore no direct theoretical connection between choice of Approach and choice of Tier. In practice, when Tier 1 methods are applied, Approach 1 will usually be used while the ability to apply Approach 2 is more likely where Tier 2 and 3 methods are being used, moreover for quantifying the uncertainty of emissions/removal estimates of complex systems such as in the AFOLU Sector. When Approach 2 is selected, as part of QA/QC activities inventory agencies also are encouraged to apply Approach 1 because of the insights it provides and because it will not require a significant amount of additional work. Where Approach 2 is used, its estimates of overall uncertainty are to be preferred when reporting uncertainties."*
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> *IPCC 2006, Vol. 1, Ch 3, Subsection 3.2.3.5 Guidance on choice of Approach*
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> *"In some cases, most of the category uncertainties in an inventory might be estimated using Approach 2, with relatively few estimated using Approach 1. It is possible to incorporate Approach 1 estimates of uncertainty for some categories into an Approach 2 methodology for combining uncertainties for the total inventory. This is done by using the uncertainty half-range obtained from Approach 1 to specify an appropriate PDF model to represent uncertainty for each category as part of the Monte Carlo simulation."*
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> *IPCC 2006, Vol. 1, Ch 3, Subsection 3.2.3.3 Hybrid combinations of Approaches 1 and 2*

Q1-3-11. What are the key differences between Approach 1 and Approach 2?

A: While Approach 1 technically is limited to specific circumstances the 2006 IPCC Guidelines give ways to deal with these situations and so it gives useful results for all emission inventories. Approach 2 does not have these limitations.

Approach 1 is only strictly correct when uncertainties are less than 0.3, distributions are normal and there are no correlations. However, the 2006 IPCC Guidelines give an empirical equation for dealing with large uncertainties and the impact of correlations can be reduced by grouping data.

Approach 2 can deal with all these situations. Approach 2 requires significantly more data and resources. It needs not just the uncertainty but also the probability density function, which can be non-symmetrical. Approach 2 will be required if a realistic quantitative uncertainty range is to be calculated in cases where large uncertainties in activity data and / or emission factors occur.

Where the standard deviation for any parameter is greater than about 0.3, normal probability functions will give non-negligible probabilities for negative values. In real life such negative values can obviously not occur. Another option would be to use a log-normal distribution in this case.

Q1-3-12. How to interpret and use the output data of the uncertainty assessment?

A: A Tier 2 KCA uses the uncertainty data together with the magnitude of each source or sink category to highlight those that contribute to the overall inventory uncertainty. Thus improvements can be targeted to reduce overall inventory uncertainty.

Both approaches give estimates of the confidence intervals of the inventory that can be used in verification (comparison with other independent estimates).

Q1-3-13. In the AFOLU sector, Approach 1 uncertainty assessment sometimes using Equation 3.2 sometimes results in extremely large uncertainty values because the denominator becomes close to zero when emissions and removals are nearly equal. Is this appropriate? Can we somehow avoid it?

A: This is because uncertainty is presented as a relative uncertainty (a fraction uncertainty divided by the point estimate). As sources and sinks balance the point estimate goes to zero but the absolute value of the uncertainties might still be significant. The calculated value of the relative uncertainty in such cases becomes very large and is not meaningful. It may be better to present absolute uncertainty values when emissions and removals nearly balance. Just show the absolute values of 95% confidence interval. These absolute values can be combined with absolute values of the rest of the inventory to give overall inventory uncertainty.

Q1-3-14. How should we treat correlation between factors in uncertainty assessment?

A: Assume there is no correlation unless there is evidence of correlation. If there is evidence, correlation should be taken into account. See IPCC 2006, Vol.1, Ch 3, p 3.25-3.26 "Dependence and correlations among inputs".

An example where correlation is likely to be important would be land use data. As the area of one land use is increasing, the areas of other land uses will by necessity be decreasing (assuming the land base is constant across the time series, which is a good practice).

This relationship creates correlations in the data which can be derived if the land survey has a statistically-based design. In this case, the compiler would need to derive the covariances across all combination of land use and time in order to fully address the uncertainty.

1.4. Questions about other Inventory Issues

Q1-4-1. Can the methods and default data of the IPCC Guidelines for National Greenhouse Gas Inventories be used in estimation of emissions/removals at scales other than national?

A: Aspects of the emissions estimation methods of the IPCC Guidelines are often applicable for use at a regional, corporate, facility or project level and their use for these purposes often assists in fostering consistency between estimation methods within a country's emissions estimation and reporting system.

Categorization of sources/sinks may not directly apply for GHG accounting at level other than national (e.g. corporate-level), particularly where boundaries are different, and where it is necessary to take account of emissions offsite (e.g. from electricity generation and waste disposal). In national GHG inventories such offsite emissions affecting the national total are allocated to the sector in which they occur (e.g. energy and waste). To take account of offsite emissions it may be necessary to attribute a part of emissions elsewhere in the national GHG inventory, using some rule or procedure to decide what is appropriate, for example a proportional or marginal share.

It is also possible that more detailed information available at the corporate, facility or project level can give results that are more accurate or precise than if, for example, IPCC defaults are used. Practical approaches to using such detailed information are discussed in the following publications available at http://www.ipcc-nggip.iges.or.jp/public/index.html:

- TFI Technical Bulletin: Use of Facility–Specific Data in National Greenhouse Gas Inventories (2012)
- Expert meeting report: Use of Models and Facility-Level Data in Greenhouse Gas Inventories (2011)

The Global Protocol for Community-Scale GHG Emission Inventories (GPC) - a GHG Protocol standard for cities (http://ghgprotocol.org/city-accounting) references methods in the IPCC Guidelines and recommends for some source categories to use IPCC default factors if local, regional, or country-specific sources are unavailable.

Q1-4-2. What are the major types of GHG inventories and what are their key differences?

A: In addition to national GHG inventories, there are inventories which are prepared at other geographic scales, e.g. sub-national inventories for administrative regions, or cities, or at the corporate or facility level. GHG assessments may also be made on a product life cycle basis. In general, key differences in the inventories include inventory boundary, categorization of emissions/removals, reporting period and approach used (e.g. top-down, bottom-up) in estimation of emissions/removals. Life-cycle estimates are likely to introduce additional complexities because of interactions and feed-backs between categories.

Q1-4-3. Where can we find EFs and parameters other than IPCC default values that can be used in estimation of emissions and removals?

A: Research conducted at a national level, by industries or trade associations and by environment agencies are useful sources. Users of the IPCC Guidelines should also consult the IPCC Emission Factor Database (EFDB), which is a library of various emission factors and other parameters with background technical information that can be used for estimation of GHG emissions/removals. The database is developed and maintained by IPCC Task Force on National Greenhouse Gas Inventories (TFI). The EFDB can be accessed at http://www.ipcc-nggip.iges.or.jp/EFDB/main.php and the EFDB user manual can be downloaded from http://www.ipcc-nggip.iges.or.jp/EFDB/documents.php. Experts with country-specific data not currently represented in the EFDB, are encouraged to submit the data/information for consideration by the EFDB Editorial Board.

Q1-4-4. Are there any IPCC calculation tools for estimation of emissions/removals and can these tools be used in inventories other than national level?

A: The IPCC TFI produced new inventory software (IPCC Inventory Software) in 2012 to assist countries in compiling, documenting and archiving a national GHG inventory. The software is based on the *2006 IPCC Guidelines*. It can also be used for checking the estimates or estimating emissions/removals from particular sources/categories. This software cannot necessarily be used at sub-national scales, because of the coverage and other issues identified in Q1-4-2 above. The IPCC Inventory Software and its user manual are freely available at http://www.ipcc-nggip.iges.or.jp/software/index.html

Q1-4-5. What is a difference between direct and indirect emissions when these terms are used in the context of national inventories, as opposed to their usage in the context of corporate inventories?

A: In national GHG inventories, direct emissions are those taking place directly from a source as consequence of an activity resulting in the emissions while indirect emissions are those occurring through indirect pathways. For example, N2O emissions from managed soils occur through both a direct pathway (i.e., directly from the soils to which the N is added/released), and through two indirect pathways: (i) following volatilisation of NH3 and NOx from managed soils and the subsequent redeposition of these gases and their products NH4+ and NO3- to soils and waters; and (ii) after leaching and runoff of N, mainly as NO3-, from managed soils.

By contrast the GHG Protocol produced by World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI) (http://ghgprotocol.org/calculation-tools/faq#directindirect) defines direct and indirect emissions as follows:

- Direct GHG emissions are emissions from sources that are owned or controlled by the reporting entity
- Indirect GHG emissions are emissions that are a consequence of the activities of the reporting entity, but occur at sources owned or controlled by another entity.

Q1-4-6. What are the ISIC Divisions that the 2006 IPCC Guidelines refer to?

A: The International Standard Industrial Classification of All Economic Activities (ISIC) is a classification developed by the United Nations Statistics Division. The latest version of the ISIC is the Revision 4 (Rev.4). The *2006 IPCC Guidelines* refer to the Revision 3.1 (Rev.3.1.) as it was the latest version at the time of development of the *2006 IPCC Guidelines*. The corresponding ISIC Divisions (Rev.3.1) can be found at the United Nations Statistics Division web-site: http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=17&Lg=1

Q1-4-7. How indirect CO_2 emissions (i.e., CO_2 inputs to the atmosphere from emissions of carbon-containing compounds) are to be estimated?

A: The relevant guidance is provided in the 2006 IPCC Guidelines, Chapter 7 Vol.1, and has been updated in the 2019 Refinement, Chapter 7 Vol.1. In those chapters, the so-called "indirect CO_2 emissions" is referred to as CO_2 inputs to the atmosphere from the transformation in the atmosphere of carbon-containing compounds. According to those guidelines, in national GHG inventories, inputs of CO_2 from the atmospheric oxidation of CH_4, CO, and non-methane volatile organic compounds (NMVOCs) are:

I. **already implicitly included for some source categories,** as for fossil fuel combustion where default CO_2 emission factors provided in the 2006 IPCC Guidelines assume that all carbon content is oxidised. In this case, indirect CO_2 emissions shall not be estimated for inclusion in national GHG inventories in order to avoid double counting. On the other hand, indirect CO_2 emissions may be estimated separately where alternative CO_2 emission factors to estimate direct emissions of CO_2 are used;

II. **intentionally excluded for some categories**, as for biogenic carbon from rapidly cycling (non-fossil) where the atmospheric oxidation of CH_4 merely completes a natural cycle and is not treated as a net anthropogenic contribution to the atmosphere's CO_2 burden (e.g. livestock enteric fermentation). Accordingly, indirect CO_2 emissions shall not be estimated for inclusion in national GHG inventories;

III. **may be estimated separately for yet other categories**, as for carbon-containing compounds emitted as fugitives from fossil fuel production, processing and storage activities, as well as from some industrial processes where fossil fuels are used as feedstock. The indirect CO_2 inputs associated with fugitive carbons emitted in the form of CH_4, CO or NMVOCs are typically not estimated elsewhere in the GHG inventories, while those from storage and emissions from non-energy use and feedstock may or may not be included elsewhere in the GHG inventories. Accordingly, CO_2 inputs to the atmosphere from the fugitive emissions of CH_4, CO or NMVOCs may be estimated separately, while those from non-energy use and feedstock may be only if not yet included in the GHG inventories.

Where needed, indirect CO_2 emissions can be estimated by quantifying the fraction of the carbon in CH_4, CO or NMVOCs that are oxidised to CO_2 in the atmosphere (oxidation factor) and by converting it into CO_2. For instance, given that the mass of CO_2 and CH_4 are 44 and 16 g/mole respectively and assuming that the oxidation factor for CH_4 ranges from 51 to 100%, indirect CO_2 emissions = $Emissions_{CH4}$ * [0.51-1] * 44/16 = $Emissions_{CH4}$ * [1.4-2.8]. For more details see the following reference in the 2019 *Refinement: Boucher O., Friedlingstein P., Collins B. & Shine K. P. (2009) The indirect global warming potential and global temperature change potential due to methane oxidation. Environmental Research Letters 4.*

Alternatively, where needed, a metric that includes the effect of CO_2 inputs to the atmosphere associated with the oxidation of CH_4 can be used in calculation of CO_2-equivalent emissions of CH_4 in the GHG inventories. For instance, the global warming potential (GWP) value for 100 years of methane is 28 without the effect of oxidation to CO_2 and 30 with that effect, according to the Table 8.A.1 of Appendix 8.A in the Working Group I Contribution to the IPCC Fifth Assessment Report. The difference between these two GWP values is consistent with the estimate of indirect CO_2 emissions from CH_4 that are derived using the method mentioned above. Of course, If the metric for CH_4 includes the effect of oxidation to CO_2 in the atmosphere, indirect CO_2 emissions should not be estimated separately to avoid double counting the warming impact.

Further details on treatment of carbon emitted in gases other than CO_2 are provided in 2019 Refinement, Volume 1, Chapter 7, Section 7.2.1.5.

2. Energy

Q2-1. Do the *Revised 1996 Guidelines* allow for dealing with storage of GHG? If yes, how could we treat the stored quantities of CO_2 according to the *Revised 1996 Guidelines*?

A: Yes, the *Revised 1996 Guidelines* allow for dealing with storage of GHG although it is not mentioned explicitly. If reporting emissions under the *Revised 1996 Guidelines*, the emissions from the plant where the gas is captured will need to be estimated along with estimates of emissions from the collection, processing, transport and injection of the GHG along with any leaks from the final storage.

It is covered in the *2006 Guidelines* more explicitly in a way that is consistent with the *Revised 1996 Guidelines*.

Q2-2. How is the demarcation between "international transport" and "domestic transport" defined in the IPCC methodology?

A: Essentially each leg of a journey is treated separately. A leg starting in one country and ending in another is international, while a leg starting in one country and ending in the same country is national.

The *2006 Guidelines* have slightly simplified the data needs for the domestic versus international split as compared to the *GPG2000*. It is very unlikely that this change would make a significant change to the emission estimates (see section 3.6.1.3 in the Energy Volume of the *2006 Guidelines* and section 2.5.1.3 in the *GPG2000* for further details).

Q2-3. Where can we find GHG emission factors for electricity use?

A: GHG emissions do not occur when and where electricity is used. Therefore the *IPCC Guidelines* do not provide emission factors for electricity use. GHG emissions occur in the generation of the electricity; the *IPCC Guidelines* enable one to estimate emissions from the combustion of fuels used to generate the electricity. (See also Q.2-4 below.)

Irrespective of emissions quantification methods, a country may wish for its own purposes to regard emissions from electricity generation as caused by electricity use. In that case, the emissions per kWh of electricity used depend on the fuels used and the efficiency of generation and transmission. Efficiency and mix of fuels varies dramatically from country to country so no general factors can be given, but given knowledge of the fuels used and the amount of electricity produced or supplied to users, suitable factors can be estimated. Note however that there may be additional local issues to be considered (e.g. imports/ exports of electricity or impact of load on fuel mix). As regards estimation of GHG emissions from hydropower, see Q.2-6 below.

Q2-4. Where can we find GHG emission factors for electricity generation?

A: The *IPCC Guidelines* do not provide emission factors for electricity generation in terms of emissions per electricity generated (kg/kWh). Instead, the *IPCC Guidelines* provide emission factors for fuels that are used to generate electricity. These are present under stationary combustion in the IPCC Guidelines (see Chapter 2 of Volume 2 Energy in the 2006 Guidelines). As regards estimation of GHG emissions from hydropower, see Q.2-6 below.

Q2-5. Where can we find GHG emission factors for combined cycle gas turbine (CCGT)?

A: The *IPCC Guidelines* use the fuel combusted (in GJ) as the activity data in all the Energy Sector source categories.

The *2006 Guidelines* have default carbon dioxide emission factors (kg CO_2/TJ) for different fuels including natural gas, the fuel mostly used in CCGT technology in Table 1.4 of chapter 1 of Volume 2. The emission depends on the carbon content and amount of fuel used.

Q2-6. Where can we find GHG emission factors for hydropower?

A: There are no globally applicable methods for estimating GHG emission from hydropower in terms of their operation. However, relevant methodological guidance can be found in the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (*2019 Refinement*). It does not provide emission factors for hydropower in terms of emissions per electricity generated (kg/kWh), but provides methods to estimate CO_2 and CH_4 emissions from the flooding of the reservoir area and downstream emissions of CH_4 from degassing (Chapter 7 in Volume 4).

The IPCC does not provide a default methodology to estimate N_2O emissions from reservoirs since those are largely related to N inputs to reservoirs from e.g. agricultural soils or through wastewater, which associated emissions are already estimated in other GHG Inventory categories.

Q2-7. Is peat classified as fossil fuel or as biofuel in the *IPCC Guidelines*? What is the scientific basis for the classification the IPCC has chosen?

A: In terms of the *Revised 1996 Guidelines*, peat or peatland appear in the Energy and the Land-Use Change and Forestry (LUCF) chapters. Peat is classified as "Solid Fossil" in the Energy Sector.

In the *2006 Guidelines* peat is not described as a fossil fuel or as biomass but as peat because "Although peat is not strictly speaking a fossil fuel, its greenhouse gas emission characteristics have been shown in life cycle studies to be comparable to that of fossil fuels (Nilsson and Nilsson, 2004; Uppenberg et al., 2001; Savolainen et al., 1994). Therefore, the CO_2 emissions from combustion of peat are included in the national emissions as for fossil fuels." (See the footnote 5 on page 1.15 in Chapter 1, Volume 2 in the *2006 Guidelines*.)

Q2-8. How can we calculate GHG emissions from charcoal production and in what category should we report them?

A: Emissions from charcoal production should be calculated using the guidance provided under source category 1.A.1.c "Manufacture of Solid Fuels and Other Energy Industries" of the *2006 Guidelines* and reported in this source category.

The *Revised 1996 Guidelines* however require non-CO_2 emissions from the production of charcoal should to be reported in 1B1 (Fugitive Emissions from Solid Fuels).

However, the use of charcoal (which is a fuel combustion activity) should be reported in 1A (in the subsection that will depend on where the fuel was used e.g. if in agriculture or fishing, it has to be reported under 1A4) both under the *Revised 1996 Guidelines* and the *2006 Guidelines*.

Q2-9. Should we include fugitive emissions of CH_4 from a natural gas pipeline which crosses multiple countries in the national total GHG emissions, or should we treat those emissions in the same way as those from "international bunker fuels"?

A: By definition, the international pipeline fugitive emissions cannot be regarded as "international bunker fuels", and hence these emissions ought to be included in national totals. Consequently, emissions from pipelines within national territories are to be included in the national inventories. According to the *IPCC Guidelines* countries should report, and include in their national total amounts, the fugitive CH_4 emissions from this kind of natural gas pipeline with a clear description of underlying logic or assumptions that prompted this action.

Q2-10. According to the IPCC Guidelines CO_2 Emissions from the combustion of biomass are reported as zero in the Energy sector. Do the IPCC Guidelines consider biomass used for energy to be carbon neutral?

A: The overall IPCC approach to estimating and reporting bioenergy greenhouse gas emissions at the national level requires complete coverage of all IPCC sectors, including the AFOLU and Energy sectors. All CO_2 emissions and removals associated with biomass are reported in the AFOLU sector. Therefore, CO_2 emissions from biomass combustion used for energy are only recorded as a memo item in the Energy sector; these emissions are not included in the Energy sector total to avoid double counting. The approach of not including these emissions in the Energy Sector total should not be interpreted as a conclusion about the sustainability, or carbon neutrality of bioenergy.

While individual methodologies and emission factors provided in the IPCC Guidelines may be relevant for estimating CO_2 emissions from the use of bioenergy at an individual facility or industry, the IPCC Guidelines as an overall framework for a national GHG inventory do not provide an analytical approach for assessing the full bioenergy emissions at sub-national entities such as industry sectors. A complete coverage of bioenergy emissions at the sub-national level – for example for an industry sector – may require additional analytical work and assumptions beyond the scope of the 2006 IPCC Guidelines to attribute all relevant bioenergy emissions (e.g. those associated with growing bioenergy crop, land-use change, fertilization, transportation, etc.) to the sub-national entities of interest.

Thus, the IPCC Guidelines do not automatically consider or assume biomass used for energy as "carbon neutral", even in cases where the biomass is thought to be produced sustainably. The methodological framework used within the IPCC Guidelines reflect the following:

1. CO_2 emissions and removals due to the harvesting, combustion and growth of biomass are included in the carbon stock changes of the relevant land use category of the AFOLU sector where the biomass originates.

2. The IPCC guidelines provide the simplifying assumption (Tier 1 method) regarding CO_2 emissions and removals associated with annual biomass (e.g., corn, colza) that over the course of a year, the CO_2 emissions from the combustion/oxidation/decay of annual biomass are balanced by carbon uptake prior to harvest, within the uncertainties of the estimates, so the net emission is zero.

3. CO_2, CH_4 and N_2O emissions and removals related to biomass production associated with land-use practices and management as well as changes in these e.g., deforestation or fertilisation and lime use, are also captured in the overall estimates provided in the AFOLU sector.

4. There may also be additional emissions that are estimated and reported in other sectors, the sector is chosen based on where the emissions occur, e.g.:
   a. from the processing and transportation of the biomass, in the Energy sector;
   b. CH_4 and N_2O emissions from the biomass combustion, in the Energy sector;
   c. CH_4 and N_2O emissions from the biogenic part of waste burned without energy recovery, in the Waste sector.

For more information, see Volume 1, Chapter 1 as well as section 2.3.3.4 "Treatment of biomass", in volume 2 of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/2_Volume2/19R_V2_2_Ch02_Stationary_Combustion.pdf)

Q2-11. How to report CCS of Biogenic CO_2?

A: In the context of national GHG inventories, carbon dioxide capture and storage (CCS) means geological carbon sequestration. Per the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines), geologic sequestration can be incorporated into GHG inventories using a Tier 3, site-specific methodology. This includes geologic sequestration of biogenic CO_2. The 2006 IPCC Guidelines note that "Once captured, there is no differentiated treatment between biogenic carbon and fossil carbon: emissions and storage of both will be estimated and reported." (Volume 2, Chapter 5, Table 5.4), and that "Negative emissions may arise from the capture and compression system if CO_2 generated by biomass combustion is captured. This is a correct procedure and negative emissions should be reported as such." (Volume 2, Chapter 5, Section 5.3). Information on Tier 3 methodologies for geologic sequestration can be found in the 2006 IPCC Guidelines, Volume 2, Chapter 5, Section 5.7, Methodological Issues.

In the case of biogenic CO_2, the negative emissions are to be reported in the IPCC sector in which capture takes place, at the most disaggregated level possible. For example, in the case of capture of fugitive emissions of biogenic CO_2 at ethanol plants that produce ethanol for fuel use, the negative emissions could be reported as capture under 1.B.3.

Relevant text
2006 IPCC Guidelines, Volume 2, Chapter 5, Table 5.1 (UNCHANGED in the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2019 Refinement))
"Carbon dioxide (CO_2) capture and storage (CCS) involves the capture of CO_2, its transport to a storage location and its long-term isolation from the atmosphere. Emissions associated with CO_2 transport, injection and storage are covered under category 1C. Emissions (and reductions) associated with CO_2 capture should be reported under the IPCC sector in which capture takes place (e.g. Stationary Combustion or Industrial Activities)."

2006 IPCC Guidelines, Volume 2, Chapter 5, Table 5.4 (UNCHANGED in 2019 Refinement)
"Once captured, there is no differentiated treatment between biogenic carbon and fossil carbon: emissions and storage of both will be estimated and reported."

2006 IPCC Guidelines, Volume 2, Chapter 5, Section 5.3 (UNCHANGED in 2019 Refinement)
Negative emissions may arise from the capture and compression system if CO_2 generated by biomass combustion is captured. This is a correct procedure and negative emissions should be reported as such.

2019 Refinement, Volume 1, Chapter 8, Section 8.2.1
"CO_2 emissions from biomass combustion for energy are reported in the energy sector as memo item and estimated and reported in the AFOLU Sector as part of net changes in carbon stocks. (NEW text) The capture of biogenic CO_2 emissions from biomass combustion, or other processes, should be treated consistently with CO_2 capture from fossil fuel combustion and reported in the Energy and/or IPPU Sectors. Once captured, and added to the carbon capture and storage process there is no differentiated treatment between biogenic carbon and fossil carbon. Both captured biogenic and fossil CO_2 should not be added to the total emissions, i.e. net emissions should be reported (also see section 5.3 of Chapter 5 in Volume 2 of the *2006 IPCC Guidelines*). Non-CO_2 emissions from biomass combustion are reported in the Energy Sector. Non-CO_2 fugitive emissions from production of fuels (e.g. charcoal or biochar) are reported in the Energy Sector (see Table 4.3.1 in Chapter 4, Volume 2 for the correct allocation of non-CO_2 fugitive emissions from fuel transformation)."

3. IPPU

Q3-1. How should we differentiate industrial process emissions and fuel combustion emissions?

A: Allocating emissions from the use of fossil fuel between the Energy and the Industrial Processes or the IPPU Sectors can be complex. The feedstock and reductant uses of fuels frequently produce gases that may be combusted to provide energy for the process. Equally part of the feedstock may be combusted directly for heat. This can lead to uncertainty and ambiguity in reporting. To help to overcome this problem, the *2006 Guidelines* introduce practical guidance on when to allocate CO_2 emissions released from combustion of fuel to the subcategory fuel combustion within the energy source category or to the industrial process source category. This rule is given in Box 1.1 in Chapter 1, Volume 3 of the *2006 Guidelines*. The guidance on this issue is less clear in the *Revised 1996 Guidelines* and the *GPG2000*. The rule given in the *2006 Guidelines* may be by and large consistently used in the context of the *Revised 1996 Guidelines* and the *GPG2000*.

Q3-2. Can we use "potential emissions" approach for estimation of emissions related to consumption of HFCs, PFCs and SF_6 to prepare national GHG inventories?

A: "Potential emissions" approach is presented as a Tier 1 method for estimation of emissions related to consumption of HFCs, PFCs and SF_6 in the *Revised 1996 Guidelines* and the *GPG2000*. Therefore, this approach can be used in the context of the *Revised 1996 Guidelines* and the *GPG2000*.

However, those emissions have been the subject of considerable study since the *Revised 1996 Guidelines* were written and the understanding of them has been greatly improved. Therefore, in the *2006 Guidelines*, the potential emissions approach is no longer considered appropriate, and the actual emissions approaches are presented as Tier 1 methods. The potential emissions approach is still described in the *2006 Guidelines* as a verification tool for completeness of sources and as a QC check of the sum of activity data per compound, which should be equal to the sum of apparent domestic consumption as calculated in the potential emissions approach. For more details, refer to Chapter 7 and Annex 2 in Volume 3 of the *2006 Guidelines*.

Q3-3. Should we deduct quantities of CO_2 for later use and short-term storage (e.g., CO_2 used for urea production, CO_2 used for production of carbonated drinks) from CO_2 emissions?

A: The approach to this issue differs between the *Revised 1996 Guidelines* and the *2006 Guidelines*. According to the *2006 Guidelines*, quantities of CO_2 for later use and short-term storage should not be deducted from CO_2 emissions except when the CO_2 emissions are accounted for elsewhere in the inventory. Examples of the exceptions include the use of CO_2 in urea production and in methanol production.

For example, according to Section 3.2, Chapter 3, Volume 3 of the *2006 Guidelines*, CO_2 recovered from ammonia production process for downstream use in urea production should be deducted from CO_2 emissions from ammonia production. When this deduction is made, it is *good practice* to ensure that emissions from urea use are included elsewhere in the inventory (e.g., in sub-category 3C3 “Urea Application” under the AFOLU Sector).

In the *Revised 1996 Guidelines*, however, this is not the case. According to Chapter 2, page 16 of Volume 3 of the *Revised 1996 Guidelines*: “The CO_2 from ammonia production may be used for producing urea or dry ice. This carbon will only be stored for a short time. Therefore, no account should consequently be taken for intermediate binding of CO_2 in downstream manufacturing processes and products.”

With this the *2006 Guidelines* improve the *Revised 1996 Guidelines*.

Q3-4. Do the IPCC Guidelines provide any methodological guidance on absorption of CO_2 through carbonation reaction associated with cement and lime?

A: No, the *IPCC Guidelines* do not provide methodological guidance on this issue. In Section 2.2 on cement production in Volume 3 of the *2006 Guidelines*, this is explained as follows.

“There is one additional issue that, while not included in the current methodology, may become relevant for consideration in the future. Free lime (CaO not part of the formulae of the clinker minerals mentioned above) released during the curing of concrete (i.e., from the hydration of the clinker minerals) can potentially re-absorb atmospheric CO_2 - a process called carbonation. However, the rate of carbonation is very slow (years to centuries)”. (Page 2.15)

Similar explanation is given also in Section 2.3 on lime production in the same volume of the *2006 Guidelines* (page 2.24).

Q3-5. Do the IPCC Guidelines provide any guidance on how to collect confidential data/information from companies or business associations?

A: Yes. It is described in Section 2.2 “Collecting Data” in Chapter 2, Volume 1 of the *2006 Guidelines*. In the *Revised 1996 Guidelines* or *Good Practice Guidance* reports (*GPG2000* and *GPG-LULUCF*), no specific guidance is given on how to collect confidential data/information although it is repeatedly mentioned that confidentiality should be protected by aggregating data/information in the inventory reporting.

The guidance given in the aforementioned section in the *2006 Guidelines* may be consistently used also in the context of the *Revised 1996 Guidelines* and the *Good Practice Guidance* reports.

4. AFOLU

Q4-1. What are managed lands?

A: Managed land has been defined as “land where human interventions and practices have been applied to perform production, ecological or social functions”.

Q4-2. Should the greenhouse gas emissions/removals in the AFOLU Sector include those occurring only on managed lands? What about those occurring over unmanaged lands?

A: The *2006 Guidelines* state that for the AFOLU Sector, “anthropogenic greenhouse gas emissions and removals by sinks are defined as all those occurring on ‘managed land’. The use of managed land as a proxy for anthropogenic effects was adopted in the *GPG-LULUCF*. The preponderance of anthropogenic effects occurs on managed lands and, from a practical standpoint, the information needed for inventory estimation is largely confined to managed lands. Although it is not necessary to report the GHG emissions occurring over unmanaged lands, it is *good practice* to quantify and track changes over unmanaged lands as well to maintain consistency in area accounting as land use change occurs. However where an event [e.g. fire] on unmanaged land leads to a transition to managed land then the emissions from the event should be reported.

Q4-3. What are the key greenhouse gases for the AFOLU Sector? What are the processes responsible for emissions/removals of greenhouse gases from the AFOLU Sector?

A: The key greenhouse gases for the AFOLU Sector are CO_2, CH_4 and N_2O.

The processes responsible for the release/absorption of these are: CO_2 uptake through photosynthesis and release through combustion and decomposition, release of N_2O through nitrification and de-nitrification and release of CH_4 through methanogenesis under anaerobic conditions in soil and manure storage, enteric fermentation and during incomplete combustion of organic matter.

Q4-4. What are indirect emissions?

A: In the AFOLU Sector, “indirect emissions” refers to the formation of greenhouse gases displaced in time and space from the activities that are their ultimate cause. The application of nitrogenous substances to fields as fertiliser leads to direct emissions of N_2O as some of the N is emitted directly and also, through volatilization, leaching or runoff of nitrogen compounds into soil, waterways and the sea, as indirect N_2O as some of this nitrogen is subsequently converted to N_2O through denitrification. Indirect N_2O emissions are dealt with in Section 4.8, Chapter 4, of *GPG2000* and Section 11.2.2, Chapter 11, Volume 4(2) of *2006 Guidelines*.

Q4-5. What method should the countries use for estimating biomass carbon gain for land remaining in the same land use category if they do not have national carbon stock inventories?

A: Countries that do not have national carbon stock inventories system should use the gain-loss method for biomass carbon gain estimation using the default data provided in the *2006 Guidelines*. They can only use the stock difference method if they have carbon stock inventories at two points in time.

Q4-6. What is the default time period for which an area subject to land use change needs to be tracked for the estimation of carbon stock changes in the dead organic matter and soil carbon pools and why?

A: For estimating the carbon stock changes during transition periods, areas subject to land use change need to be tracked for a period required for the carbon pools to reach steady state levels of carbon. The default time period is 20 years for Tier 1 methods. However, under Tier 2 and 3 methods, this time period can be varied depending on the vegetation and other factors that determine the time required for the pools to reach steady state.

Q4-7. What is meant by the "equivalence" or "synchrony" of CO_2 emissions and removals? When is it reasonable to assume equivalence of CO_2 emissions and removals when considering CO_2 emissions due to fire?

A: "Equivalence" of CO_2 emissions and removals means that the CO_2 emissions would be counterbalanced by CO_2 removals from the subsequent re-growth of the vegetation within one year. This assumption is generally reasonable for land uses such as burning of grassland, annual crop and agricultural residues. However care must be taken to check whether woody vegetation is not lost in the process or if the grazing is the predominant use in the Forest land that is regularly burnt. In such cases net carbon stock change due to burning should be reported.

Q4-8. What are the three different Approaches to data collection and representation of land employed in the AFOLU Sector greenhouse gas estimation? When should they be used? Is there any correspondence between the approaches and the Tiers used for estimation of greenhouse gas emissions from the AFOLU Sector?

A: There are three Approaches to spatial data collection and representation as laid out in the *2006 Guidelines* viz. Approach 1, 2 & 3. These refer to the different ways in which area data could be collected and represented for greenhouse gas inventory purposes of the AFOLU Sector. The *2006 Guidelines* define these as: "Approach 1 identifies the total area for each individual land-use category within a country, but does not provide detailed information on the nature of conversions between land uses. Approach 2 introduces tracking of conversions between land-use categories. Approach 3 extends the information available in Approach 2 by allowing land-use conversions to be tracked on a spatially explicit basis. Countries may use a mix of Approaches for different regions over time."

Tiers on the other hand represent the methodological complexity required to estimate the emissions and removals from a given category given its influence on a country's total inventory, data availability and national circumstances. The use of particular Approach or a mix of Approaches for a Tier 1, 2 or 3 method will depend on the stratification schemes used for the inventory purposes. Further information on this topic is available in Chapter 3, Vol. 4 of the *2006 Guidelines*.

Q4-9. Are there any methodologies available for calculation of N_2O emissions from offsite decay of organic matter from horticultural peat?

A: Currently there are no methodologies available for estimation of N_2O emissions from the offsite decay of organic matter from horticultural peat, because generally nitrogenous fertilizers are added to the horticultural peat before use, and will likely dominate most of such emissions. In order to avoid double counting of the N_2O emissions from fertilizer use, the offsite emissions of N_2O from the decay of organic matter from horticultural peat are excluded from the N_2O emissions from lands managed for peat extraction.

Q4-10. What are the variables behind the IPCC default emission factors for enteric fermentation?

A: The variable for enteric fermentation CH_4 EF for dairy cows takes into account regions, weight, weight gain per day, feeding situation, milk per day, working hrs per day, % pregnant, digestibility of feed, and CH_4 conversion, and for non-dairy cattle, weight, weight gain per day, feeding situation, milk per day, working hrs per day, % pregnant, digestibility of feed, CH_4 conversion, and day weighted population mix.

Table 10A.3 in the *2006 Guidelines* presents the data for estimating Tier 1 enteric fermentation CH_4 EF for buffalo. The parameters considered are subcategory, weight, weight gain, feeding situation, milk per day, work hours per day, % pregnant, digestibility of feed, CH_4 conversion factor and day weighted population mix.

The relevant sections of Chapter 4 of the *Revised 1996 Guidelines*, and Chapter 10, Volume 4 of *2006 Guidelines*, dealing with emissions from livestock and manure management can be accessed at http://www.ipcc-nggip.iges.or.jp/public/gl/invs6.htm and
http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.htm respectively.

Q4-11. Can we obtain removal units (RMUs) under the Kyoto Protocol from avoided emissions associated with peat mining operations in wetland/peatland area?

A: While the *IPCC Guidelines* provide estimation methods for managed wetlands and peat lands, but questions relating to all accounting issues under the Kyoto Protocol are beyond the scope of the IPCC-NGGIP. UNFCCC may be approached for some advice on this issue.

Q4-12. Are there any trans-boundary issues involved in estimation of indirect N_2O emissions from inputs to managed soil? If so is it reasonable to use country specific emission factors?

A: No. The method presented in Volume 1, Chapter 7, and Section 7.3 of the *2006 Guidelines* attributes all indirect N_2O emissions resulting from N inputs to managed soils to the country of origin of the atmospheric NO_x and NH_3, rather than the country to which the atmospheric N may have been transported.

Q4-13. Do the guidelines take into account the creation of black or inert carbon stock?

A: Post fire residues consist of a small amount of char apart from burnt and partially burnt residues. This char or black carbon is highly resistant to decomposition due to its chemical nature. The current knowledge of its formation and turnover rates being very limited, it has not been possible to develop reliable methodologies for inventory purposes. However the *2006 Guidelines* include the technical basis for further methodological development in Appendix 1 of Volume 4.

Q4-14. How is the long term storage of carbon in wood products treated?

A: This is covered by the Harvested Wood Products section. The default assumption is that the stocks are stable – which implies emissions are equal to harvest. In the guidelines there are a number of approaches to dealing with this where this assumption is not true. The UNFCCC has not yet decided which approach to use.

Q4-15. How are emissions from wetlands treated?

A: CO_2 emissions are generally assumed to be covered by upstream carbon stock changes or are associated with the lifecycle of the resident vegetation. Peat extraction and flooded land are exceptions; in peat extraction sites, CO_2 emissions are caused by the needed drainage and C stock losses are caused by the extraction of peat for horticultural use. Emissions from horticultural peat are reported under the category 3.B.4 (Wetlands), while CO_2 emissions from peat used for energy production are reported in the relevant source categories of the energy sector. Also CH_4 and N_2O emissions occur from organic matter resident in wetlands (e.g. flooded land, managed peatlands etc.) as consequence of both processes of drainage and rewetting and are reported in categories 3.C.4 (Direct N_2O emissions), 3.C.8 and 3.C.9 (CH_4 emissions from drained land, limited to peatlands extraction sites), and 3.C.10, 3.C.11 and 3.C.13 (CH_4 emissions from rewetted land). N_2O emissions may also occur from nitrogen volatilization and its deposition on water surfaces as ammonia and nitrogen oxides, as well as nitrogen inflow from catchment or surface runoff; however, those N_2O emissions are not reported separately as wetlands, since these emissions are already included in estimates of indirect N_2O emissions from managed soils and manure management (3.C.5 and 3.C.6), wastewater treatment and discharge (4.D). Finally, N_2O emissions occurs also as consequence of fish excretions in aquaculture ponds constructed on coastal wetlands (3.C.12).

Drainage of wetlands causes a decrease in total CH_4 emissions and an increase of CO_2 and N_2O emissions (because of rapid oxidation of organic matter and associated nitrification/denitrification of N released). The rewetting of drained soils has the opposite effect of boosting CH_4 emissions in anaerobic conditions and reducing CO_2 and N_2O emissions almost to zero.

For details of methodological guidance on drained organic soils, see *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, as well as the *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. For details of methodological guidance on rewetted organic soils and aquaculture ponds, see the *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*. For methodological guidance on emissions from Flooded Land, see Chapter 7 in Volume 4 of the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Categories 3.C.8, 3.C.9, 3.C.10, 3.C.11, 3.C.12 and 3.C.13 have been added to the 2006 IPCC Guidelines framework by the *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*.

Q4-16. Should a country wish to report the CH_4 emissions from termites, do the IPCC Guidelines provide methodologies to estimate these?

A: The *2006 Guidelines* provide that "… some biomass losses can lead to emissions of C other than as CO_2, such as biomass consumption and emission as methane (CH_4) by termites and wild mammals. Default Tier 1 methods for these sources have not been developed, and countries wishing to estimate and report these emissions should develop and employ a Tier 3 approach".

Q4-17. How can N_2O measurements at site level be aggregated to derive a statistically correct national estimate?

A: Data sets of annual N_2O emissions from managed soils usually show a skewed frequency distribution – often log-linear. This means that many data of low N_2O emissions are contrasted against few data of high N_2O emissions from hotspots. Given the many factors that influence N_2O emissions and the high diversity of managed soils at national level with regard to climate, soil and management it is unlikely that the data sets are representative for all factor combinations in a country. Therefore, a simple averaging of available data will most likely not lead to a robust estimate of the national emissions when taking the arithmetic mean. Conversely, taking the median or geometric mean risks the underestimation of emissions if hotspots are under-represented (e.g. over-fertilized areas, high-intensive areas, horticulture and vegetables). It is a good practice to stratify the available data by factor combinations that explain the variation in the measured annual N_2O emissions and then to aggregate the stratified data by arithmetic means weighted by the area of each stratum. A stepwise procedure of calculation is described below, taking direct N_2O emissions from cropland as example.

Step 1: Check and document that the N_2O measurements at site level are robust, scientifically sound, reviewed (by peer review or expert review).

- Measurements should extend at least over one full year, better over several years, so that climate variability at site level and whole crop rotations can be considered where relevant.
- Measurements need to adequately cover the periods of the year in which significant N_2O emissions and N_2O emission peaks can occur. In particular, phases of freeze-thawing, rewetting of dry soil (e.g., at the beginning of the rainy season, after summer drought), high rainfall events and the month after management activities (N fertilization, tillage, harvest, incorporation of crop residues) have to be adequately covered by observations.

Step 2: Check and document whether and to what extent the measured data represent the national cropping systems with respect to:

- Climate (mean annual temperature, annual temperature range, days with frozen soil, annual rainfall, monthly rainfall patterns, length of dry season)
- Soil type
- Management (crop type, yields, N fertilization rates, N fertilizer types, tillage).

Compare the frequency distribution of the ensemble of measured site-years with the frequency distribution of the national cropping systems properties for the criteria mentioned.

Step 3: Average N_2O emissions per stratum
Stratify the data by forming classes of similar climate, soil and management so that the variability of N_2O emissions per stratum is minimized. Calculate the arithmetic mean and uncertainty (95% confidence interval) of each stratum.

Step4: Total national N_2O emissions
Quantify the area of each stratum.
Calculate the total national N_2O emissions by summing up the arithmetic means per stratum weighted by the area per stratum:

$$E_{N2O} = S_i[E_{N2O,i} * A_{Stratum,\, i}] * 10^{-6}$$

Where:

E_{N2O} = National soil N_2O emissions, Gg N_2O yr^{-1}

$E_{N2O,i}$ = Average soil N_2O emissions for stratum i, kg N_2O ha^{-1} yr^{-1}

$A_{Stratum,\, i}$ = Area of the stratum corresponding to similar climate, soil and management, ha

Q4-18. Can $Frac_{GASF}$ be further stratified by fertilizer type?

A: Yes, it is possible to stratify $Frac_{GASF}$ by fertilizer type. For example, the EMEP/EEA air pollutant emission inventory guidebook 2009 gives defaults for $Frac_{GASF}$ as NH_3 by fertilizer type. The defaults are summarised in Table 3-2 of Chapter 4-D, page 14. The defaults are calculated by linear regression against spring temperature, which is assumed to be the main period of the year in which the fertilizer is applied. This temperature must be adapted to national conditions. Alkaline soils can increase NH_3 emissions by shifting the physico-chemical equilibrium between NH_4^+ and NH_3 to NH_3.

The methodology and defaults have been developed under the European Monitoring and Evaluation Program (EMEP) to guide the national reporting under the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (CLRTAP) and therefore rely on European data. However, the defaults in Table 1 rely on physical principles and therefore have a wider applicability.

Inventory agencies need to check whether their national conditions match the calibration range of the defaults in Table 1 and may wish to seek further guidance with the UNECE's Task Force on Emission Inventories and Projections (http://www.tfeip-secretariat.org/).

Table 1. Emission factors for total NH_3 emissions from soils due to N fertilizer volatilization and foliar emissions for various climatological regions

Table 3-2 Emission factors for total NH_3 emissions from soils due to N fertiliser volatilization and foliar emissions for various climatological regions with adjustments for emissions on soils of pH > 7.0. Values are kg NH_3 volatilized per kg fertiliser-N applied and the mean spring temperature t_s (in °C). Derived from van der Weerden and Jarvis (1997) and expert judgement

Fertiliser type	EF_i	Multiplier c
Ammonium sulphate	$= 0.0107 + 0.0006\ t_s$	[1)]10
Ammonium nitrate	$= 0.0080 + 0.0001\ t_s$	1
Calcium ammonium nitrate	$= 0.0080 + 0.0001\ t_s$	1
Anhydrous ammonia	$= 0.0127 + 0.0012\ t_s$	4
Urea	$= 0.1067 + 0.0035\ t_s$	1
Nitrogen solutions	$= 0.0481 + 0.0025\ t_s$	1
Ammonium phosphates	$= 0.0107 + 0.0006\ t_s$	[1)]10
Other NK and NPK	$= 0.0080 + 0.0001\ t_s$	1

Note
[1)] The multipliers are used when these fertilisers are applied to soils with pH > 7.0 (Harrison and Webb, 2001).

Source: EMEP/EEA air pollutant emission inventory guidebook 2009

Reference

EMEP/EEA(2009) **EMEP/EEA air pollutant emission inventory guidebook**. http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009/part-b-sectoral-guidance-chapters/4-agriculture/4-d/4-d-crop-production-and-agricultural-soils.pdf

Q4-19. Can $Frac_{GASM}$ be further stratified by manure type?

A: Yes it is possible to stratify $Frac_{GASM}$ by manure type. For example, the EMEP/EEA air pollutant emission inventory guidebook 2009 gives defaults for $Frac_{GASF}$ as NH_3 by animal category and manure management system. The methodology relies on the estimation of the fraction of mineral nitrogen in the form of NH_4^+-N in the manure, called “total ammoniacal nitrogen, TAN” and follows the N flow through the animal husbandry system. The defaults given cannot be simply taken from e.g. Table 4-8 (Chapter 4-B, page 26) but have to be included in a N flow model as described in the methodology.

The methodology and defaults have been developed under the EMEP (monitoring and evaluation of long range transmission of air pollution) to guide the national reporting under the UNECE CLRTAP and therefore rely on European data. The defaults strongly depend on animal management systems, manure storage conditions, and manure application technology. Inventory agencies need to check whether their national conditions match the calibration range of the methodologies and defaults in the Guidebook and may wish to seek further guidance with the UNECE's Task Force on Emission Inventories and Projections (http://www.tfeip-secretariat.org/).

Reference

EMEP/EEA (2009) **EMEP/EEA air pollutant emission inventory guidebook 2009**.
http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009/part-b-sectoral-guidance-chapters/4-agriculture/4-b/4-b-animal-husbandry-and-manure-management.pdf

Q4-20. Can $Frac_{LEACH}$ be further stratified by using climate indices?

A: Yes, $Frac_{LEACH}$ can be stratified using climate indices. For example, Canada is using stratified $Frac_{LEACH}$ values in its national inventory by using the ratio of precipitation *P* over potential evapotranspiration *PE* (see figure). This equation results in a maximum $Frac_{LEACH}$ of 0.3 for humid climates and a minimum $Frac_{LEACH}$ of 0.05 in arid climate, assuming that even in dry climate there is the possibility of nitrate leaching, e.g., by heavy rain infiltrating through cracks in dry soil. For the climate zones in-between, a linear decrease in $Frac_{LEACH}$ is assumed. The regression shown in the figure has been derived from field studies in typical climate zones and soil regions of Canadian agriculture.

This approach could be adopted elsewhere and verified against measurements for the major soil types in the respective climate zones.

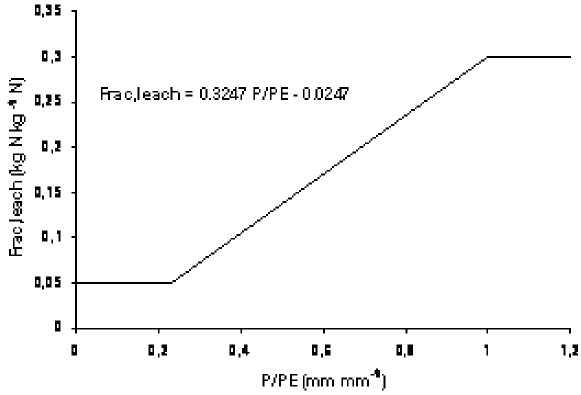

Figure 1. Determination of the Ecodistrict FRACLEACH values

Source: Canada, National Inventory Report 1990–2008

Reference

Environment Canada (2010) **Canada National Inventory Report 1990–2008**.
http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/5270.php

Q4-21. Are there default values for calculating soil water holding capacity?

A: Although there are no default values for water holding capacity given in the IPCC Guidelines, these values are available from scientific literature. Soil texture has an important influence on water holding capacity.

Water holding capacity associated with a particular soil series is generally expressed as the water available for plant use in the *root zone* (Table 2). Available soil water content is commonly expressed as inches/foot or cm/m of soil. For example, the water available can be calculated for a soil with fine sandy loam in the first foot, loamy sand in the second foot and sand in the third foot. The top foot would have about 2.0 inches, the second foot would have about 1.0 inch and the third foot would have about 0.75 inches for a total of 3.75 inches of available water for a crop with a 3 foot root depth.

Table 2. Available Soil Moisture Holding Capacity for Various Soil Textures (after Scherer et al., 1996)

	Available Soil Moisture			
Soil Texture	**inch/inch**	**inch/foot**	**cm/cm**	**cm/m**
Coarse Sand and Gravel	0.02 to 0.06	0.2 to 0.7	0.02 to 0.06	2 to 6
Sands	0.04 to 0.09	0.5 to 1.1	0.04 to 0.09	4 to 9
Loamy Sands	0.06 to 0.12	0.7 to 1.4	0.06 to 0.12	6 to 12
Sandy Loams	0.11 to 0.15	1.3 to 1.8	0.11 to 0.15	11 to 15
Fine Sandy Loams	0.14 to 0.18	1.7 to 2.2	0.14 to 0.18	14 to 18
Loams and Silt Loams	0.17 to 0.23	2.0 to 2.8	0.17 to 0.23	17 to 23
Clay Loams and Silty Clay Loams	0.14 to 0.21	1.7 to 2.5	0.14 to 0.21	14 to 21
Silty Clays and Clays	0.13 to 0.18	1.6 to 2.2	0.13 to 0.18	13 to 18

Reference

Scherer, T. F., Seeling, B. and Franzen, D. (1996) **Soil, Water and Plant Characteristics Important to Irrigation**. EB-66.
http://www.ag.ndsu.edu/pubs/ageng/irrigate/eb66w.htm

Q4-22. Are there default values for additional crop types not included in Table 11.2 of the 2006 IPCC Guidelines, e.g. of sugar cane?

A: For sugar cane, default values of dry matter fraction are given in the GPG (2000), Chapter 4, table 4.16.
Possible sources of information on dry matter fraction of important crops are the FAOSTAT Agricultural database and National Agricultural Statistics of countries where sugarcane is a major commodity. For example, sugar cane residue left for decay used in Senegal is 6.5 t of dry matter per ha.(based on field estimates).

Q4-23. How can one derive country-specific service life data for HWP?

A: An assignment of service life may be made for each category of semi-finished product (e.g. sawnwood, wood based panels, paper and paperboard) as is done for Tier 1 of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* or a Tier 3 method is to assign a service life for all semi-finished wood products in a finished application (e.g. entire buildings of a given type, wooden building components, utility poles, wooden furniture, pallets). This would require country-specific data on production of semi-finished products according to their finished application categories (For examples, see FAQ 4-24). After service life is determined for semi-finished product categories or finished application categories a decay function is assigned that uses the service life data to estimate the decay profile or the actual time path that products take to go out-of-use. The Tier 1 methods use first order decay function and Tier 3 decay functions can take a form that better represents their decay profile.

For some countries service life data for finished wood products may be available from manufacturers (e.g. for housing components or entire housing units). This data may overestimate actual use life but could suggest an upper limit on use life. Large users of certain specialty products like utility poles, fence posts, and pallets should have some idea of the replacement time of these products. Some countries may have data on houses or other buildings built in given years and also have data for current or recent years on how many houses of given ages are still in use. By comparing houses built, say 20 years ago, with the number currently standing that are 20 years old we can get an estimate of how quickly they go out of use. This may be a rough estimate because buildings may change use from commercial to residential or the reverse over time.

Methods to estimate service life for building components may be found in the ISO 15686 standard series (2011). Additional information on service life prediction may be found e.g. in Davies and Wyatt (2004) and Brischke *et al.* (2006). Use of models may also help estimate the half-life (as a function of service life) of products in use as described under Question 4-24 d) below.

It is important to note that service life of HWP can differ notably among countries (and within countries) depending on factors such as construction practices, culture, fashion, and climate.

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http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=45798
(Accessed Nov 17, 2011)

Q4-24. Can you point me toward some examples of the use of Tier 3 methodologies in the estimation of the HWP contribution?

A: Before considering use of Tier 3 methods it is recommended that users compute HWP contribution using the HWP spreadsheet provided with the 2006 IPCC Guidelines (Tier 1 method). These results will serve as a reference case to which Tier 2 and Tier 3 results can be compared. Tier 2 methods are those that continue to use the IPCC HWP spreadsheet but use country data for: 1) product production and trade; 2) conversion factors to carbon; and 3) half-lives for products.

There have been several Tier 3 refinements that countries have used to improve estimates of annual HWP contribution. These include (but are not limited to):

a) allocating primary solidwood product consumption (lumber and panels) to end uses (e.g., housing, furniture etc.) then using half-lives for end uses to estimate how long carbon is held in the end uses (Bache-Anreassen 2009; Skog 2008);

b) allocating primary wood and paper products to 5 end use pools that differ in longevity and within these pools using 3 different age groups and allowing for slow shift between the first and second groups and faster shift from the second and third groups and from the third age group to landfills, energy or recycling (Richards *et al.* 2007);

c) obtaining more accurate estimates of half-lives for products in use by selecting end use half-lives that cause the HWP model estimates of total wood carbon stocks in housing, furniture, etc. in a given year (e.g. 2001) to match an independent estimate of the wood carbon inventory in those end uses (Bache-Anreassen 2009; Skog 2008);

d) obtaining more accurate estimates of half-lives for paper and solidwood products by selecting end use half-lives that cause the HWP model estimates of discards to solidwaste disposal sites (for one or more years) to match independent estimates of the paper and solidwood products placed in SWDS (Skog 2008);

e) using statistics on building stocks and stocks at two or more points in time to estimate change in carbon held in solidwood products between those points in time (Statistics Finland 2010);

f) providing more refined estimates of discard rates for products by using equations/ procedures other than the default first order decay curve provided in the 2006 IPCC guidelines (Richards et al 2007; Marland et al 2009).

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[1]UNFCCC. 2011.
http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/5270.php

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[1]A number of countries have published HWP contribution estimates using Tier 2 methods by using country data for 1) product production and trade, 2) conversion factors to carbon, and 3) half-lives for products.

Q4-25. How can one perform calibration and verification for Tier 3 methodologies by:

a) Comparing flow estimates with a stock inventory estimates, e.g., carbon in housing stocks
See Q4-24 c) & e) above

b) Comparing using different decay curves e.g., Gamma curve or lognormal curve instead of the exponential decay curve
See Q4-24 a) and f) above. It is essential to identify the appropriate decay function to use with either the categories of semi-finished products or with categories of finished applications of wood products. For example, for very long-lived applications of finished products, the first order decay used in the default methodology is unlikely to be accurate in initial years because removal from use can be slower than estimated by first order decay and one might ask about the true probability distribution of removals from use and how much it deviates from first-order decay. For very short-lived finished applications of products, however, such as newspapers, a first-order decay curve in combination with low half-life values might describe a realistic probability distribution of carbon loss from the pool. The greater the portion of long-lived finished applications of products, the more one might want to consider what the probability distribution - particularly in early years of use - really looks like. Marland et al. (2009) provide an explanation of first order decay along with some of the alternatives and their implications.

c) Comparing HWP estimates of discards to SWDS to Waste sector AD on discards
See Q4-24 b)&d) above

Q4-26. The Equation 12.3, Chapter 12 of 2006 IPCC Guidelines assumes that round wood exports are being used for solid wood and paper products in the same proportion in the importing countries as domestically. Is this assumption correct and can this estimate be improved if the countries have more detailed data?

A: Equation 12.3, Chapter 12 of *2006 IPCC Guidelines* assumes that roundwood exports are being converted in the importing countries using the same technologies (conversion efficiencies) and made into the same mix of products as in the home nation and that the products go into uses that have the same average half-life in end uses as in the home country. This, although almost always not true can be a useful approximation. Depending on the countries' trade balance for roundwood and industrial residues (i.e. ratio in parenthesis of Equation 12.3 is less than or greater than>1), as well as the subsequent processing and the final utilization of the wooden material in export markets, this assumption can result in an over or under estimate of carbon in the HWP pool. The assumption can lead to an over estimate to the extent that exported wood chips and wood residues are used for fuel rather than solid wood or paper products. The uncertainty associated with this approximation can be dealt with in two ways.

One way to account for this uncertainty is in the uncertainty analysis. The uncertainty analysis can assume a wide uncertainty range for the fraction of exported roundwood that ends up in products and a wide uncertainty range for the half-life for those products in use.

Another way to work to improve this approximation is by seeking information – from countries that import most of the home country's products – on the allocation of those products (among solidwood and paper products) and the half-lives for those products. This would require information provided by those importing countries. With such improvement in estimates the uncertainty of estimates could be reduced.

Q4-27. What are 'garden and park waste' HWP categories and what is the correlation of these with the Waste sector categories in the Waste spreadsheet?

A: The HWP chapter (Chapter 12, Vol. 4(2)) in the *2006 IPCC Guidelines* defines HWP to include "garden" and "park" waste that are discarded to Solid Waste Disposal Sites (SWDS). The guidance on HWP indicate that estimates of HWP carbon stock-change in SWDS are to be made using the spreadsheet provided in the Waste sector guidelines and that, "It is assumed that HWP carbon in SWDS equates to the "garden", "wood" and "paper" waste categories" (that are used in the Waste sector guidelines). "Garden" (garden and park) waste includes whole trees and tree trimmings, and possibly some wood products such as fence posts or other wood products used in gardens or parks. Whole trees and tree trimmings are not a part of harvested wood products in end uses since they go directly from the land to a SWDS. But it may be possible that a few wood products such as fence posts are part of HWP in "products-in-use".

Q4-28. Where have the definitions for the Equation 12.5, Chapter 12 been given?

A: The definitions for the Equation 12.5, Chapter 12 are given in Table 12.1, p. 12.8, Chapter 12, Volume 4(2) of the *2006 IPCC Guidelines*.

Q4-29. What does the line: "The decay of HWP is assumed to be of first order" in Section 12.2.1.1, Chapter 12 mean? Does it just mean loss of carbon due to biological decay?

A: It does not refer to biological decay. Here "decay" refers to the discarding of wood and paper products from end uses. "First order" is used to describe an assumption about the rate of discarding of products from end uses. A first order process (from chemistry) is one where the rate of change depends on the quantity of material. This means the amount of wood or paper product that goes out of use at a point in time and is a constant percentage of the amount currently in use. This assumption about "decay" can be expressed as an exponential function.

The reference to "the decay of HWP is assumed to be of first order" indicates that the rate at which wood products are discarded from end uses (and sent to solid waste disposal, are recycled, burned, composted etc.) follows an exponential (first order) curve. That is, the amount discarded at a given point in time is a constant percent of the amount held in end uses. Discarding does not mean a product is oxidized. Carbon in products sent to SWDS or recycled will continue to be stored. This amount of storage after initial discarding can be accounted for in the IPCC estimation methods by the estimated additions of HWP carbon to SWDS or by tracking production of paper using recovered paper or by increasing the half-life (or otherwise changing the decay curve) for solidwood products to include recycling of solidwood products. It is important to keep in mind that there is a difference between the end of service life of a product and oxidation of the product to release CO_2. Ideally we would like to know the later but practically it is easier to obtain information on the former. However it may also be important to take into account the fate of products after they are discarded, including recycling and re-use of materials.

It is important to note that the carbon in HWP that is discarded to SWDS may be overestimated, as biological decay while in service (e.g., due to termite or fungal activity) is not taken into account.

Q4-30. How the IPCC Climate Zone Map has been calculated?

A: The IPCC Climate Zone Map reported in Figure 3A.5.1 in Chapter 3 of Vol.4 of 2019 Refinement has been produced by authors applying the classification scheme, reported in Figure 3A.5.2, on the gridded Climate Research Unit (CRU) Time Series (TS) monthly climate data for the period from 1985 to 2015 -CRU4.00- following the methodology described by Harris et al. (in Harris, I., Jones, P. D., Osborn, T. J. & Lister, D. H. (2014) Updated High-resolution Grids of Monthly Climatic Observations - the CRU TS3.10 Dataset. International Journal of Climatology 34(3): 623-642).

The dataset can be downloaded here, the paper here, while the ***raster*** and ***vector*** versions for the map can be downloaded by clicking on the respective word. Where a dataset with higher spatial resolution is available, users may recalculate accordingly recalculate the climate zone map by applying the classification scheme of Figure 3A.5.2.

5. Waste

Q5-1. Should we estimate and report CO_2 emissions from wastewater treatment?

A: No. CO_2 emissions from wastewater treatment are not included in the national total in the *IPCC Guidelines* since these are assumed to be of biogenic origin, because any net changes in carbon stock of biogenic origin is covered in the AFOLU Sector.

Q5-2. How should we treat CO_2 emissions from waste incineration, where the waste is of mixed biogenic and non-biogenic material?

A: Distinctions between carbon of biogenic and non-biogenic origins have to be made, because any net changes in carbon stock of biogenic origin is already covered in the AFOLU Sector. The method to estimate the non-biogenic carbon fraction is described in Sections 2.3 and 5.4.1.2. of the Waste Volume of the *2006 Guidelines*.

In the absence of energy recovery by the incineration of waste, CO_2 emissions from the incineration of non-biogenic carbon in the waste are considered as net emissions and reported under the Waste Sector while those of biogenic carbon in the waste should not be included in national total.

Where the incineration of waste is used for obtaining energy, CO_2 emissions from non-biogenic carbon need to be reported under the Energy Sector. Emissions from biogenic carbon should be reported as information items under the Energy Sector, hence, not included in the national total.

Q5-3. Can the mass-balance approach be used for waste disposal sites where historical data are not available?

A: The mass-balance method is included in the *Revised 1996 Guidelines* and *GPG2000* and so is consistent with the requirements for Annex 1 parties, where a higher tier method is not indicated by the decision tree (*GPG2000*, Fig 5.1).

However, the *Revised 1996 Guidelines* allow inventory compilers to choose any methods with which they believe would improve their inventories beyond the default methods and/or make them more complete. The authors of the *2006 Guidelines* believe that their first order decay (FOD) approach was an improvement over the mass-balance approach, even when there is only a single years worth of data. Therefore if Inventory compilers do not have historical data they should consider using the FOD method together with the guidance on data collection and ways of dealing with a lack of historic data.

Abbreviations

- IPCC = Intergovernmental Panel on Climate Change
- UNFCCC = United Nations Framework Convention on Climate Change
- GHG = greenhouse gas
- GWP = Global Warming Potential
- SAR = Second Assessment Report (IPCC, 1995)
- TAR = Third Assessment Report (IPCC, 2001)
- AR4 = Fourth Assessment Report (IPCC, 2007)
- AR5 = Fifth Assessment Report (IPCC, 2013/2014)
- Revised 1996 Guidelines = Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1996)
- GPG2000 = Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000)
- GPG-LULUCF = Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC, 2003)
- 2006 Guidelines = 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006)
- LUCF = Land-Use Change and Forestry
- LULUCF = Land Use, Land-Use Change and Forestry
- IPPU = Industrial Processes and Product Use

AFOLU = Agriculture, Forestry and Other Land Use