2019 REFINEMENT TO THE 2006 IPCC GUIDELINES FOR NATIONAL GREENHOUSE GAS INVENTORIES

OVERVIEW

First Draft

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1 INTRODUCTION

The *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (*2006 IPCC Guidelines*) which were published in 2006 provide methodologies for estimating national inventories of anthropogenic emissions by sources and removals by sinks of greenhouse gases. This IPCC Methodology Report titled the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (*2019 Refinement*) was published in 2019 to refine the *2006 IPCC Guidelines* with the aim to provide an updated and sound scientific basis for supporting the preparation and continuous improvement of national greenhouse gas inventories.

In order to achieve this overall aim, the *2019 Refinement*:

- Provides supplementary methodologies for sources or sinks of greenhouse gases only where currently there are gaps or where new technologies and production processes have emerged requiring elaborated methodologies or for sources or sinks that are not well covered by the *2006 IPCC Guidelines*;
- Provides updated default values of emission factors and other parameters based on the latest available scientific information only where significant differences from default values presented in the *2006 IPCC Guidelines* are identified;
- Provides additional or alternative up-to-date information and guidance, where possible, as clarification or elaboration of existing guidance in the *2006 IPCC Guidelines*.

The *2019 Refinement* does not revise the *2006 IPCC Guidelines*, but updates, supplements and/or elaborates the *2006 IPCC Guidelines* where gaps or out-of-date science have been identified. It does not replace the *2006 IPCC Guidelines*, but should be used in conjunction with the *2006 IPCC Guidelines* and the *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands* (*Wetlands Supplement*).

2 BACKGROUND

The Bureau of IPCC Task Force on National Greenhouse Gas Inventories (TFB), at its 26th meeting held in Ottawa, Canada in August 2014, concluded that:

- The *2006 IPCC Guidelines* provide a technically sound methodological basis of national greenhouse gas inventories, and therefore fundamental revision was unnecessary.
- To maintain the scientific validity of the *2006 IPCC Guidelines*, certain refinements might be required, taking into account scientific and other technical advances that had matured sufficiently since 2006.

Following these conclusions by the TFB and also in accordance with the approval by the IPCC at its 40th Session held in Berlin, Germany in April 2014, the Task Force on National Greenhouse Gas Inventories (TFI) started a technical assessment of IPCC inventory guidelines through an on-line questionnaire survey and four expert meetings in 2015 and 2016[1,2,3,4].

The technical assessment revealed that there had been abundant new scientific and empirical knowledge published since 2006 that the IPCC should take into account, particularly with respect to data for emission factor development for some categories and gases. Consequently, the TFB recognized the necessity and usefulness of refining the *2006 IPCC Guidelines* (e.g. updating default emission factors), and concluded that the refinement should be made as early as possible so as to help all the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) use *good practice* inventory methodologies based on up-to-date scientific knowledge.

The IPCC, at its 43rd Session in Nairobi, Kenya in April 2016, approved the proposal made by the Co-Chairs of TFI on "Refinement of 2006 IPCC Guidelines for National Greenhouse Gas Inventories, including production of a Methodology Report(s)" as contained in the Decision IPCC/XLIII-8 "Update of methodologies on National Greenhouse Gas Inventories". At the same session, the IPCC decided to consider the outline of the new Methodology Report(s) at the 44th Session of the IPCC in October 2016 and to consider the draft Methodology Report(s) at a Plenary session of the IPCC in May 2019 (Decision IPCC/XLIII-7 "Sixth Assessment Report (AR6) Products. Strategic Planning"). Following this decision, a scoping meeting for a Methodology Report(s) to refine the *2006 IPCC Guidelines* was held in Minsk, Belarus in August 2016. The outcome of the scoping meeting was approved by the TFB at its 28th meeting which was held immediately after the scoping meeting, and submitted to the IPCC for consideration. Finally the IPCC, at its 44th Session in Bangkok, Thailand, decided to prepare the *2019 Refinement* and adopted its scope and outline (Decision IPCC/XLIV-5 "Sixth Assessment Report (AR6) Products, Outline of the Methodology Report(s) to refine the 2006 Guidelines for National Greenhouse Gas Inventories").

[1] Expert Meeting for Technical Assessment of IPCC Inventory Guidelines (Energy, IPPU, Waste Sectors), 29 June - 1 July 2015, Geneva, Switzerland

[2] Expert Meeting for Technical Assessment of IPCC Inventory Guidelines (AFOLU Sector) 13-16 July 2015, São Paulo, Brazil

[3] Expert meeting for Technical Assessment of IPCC Inventory Guidelines: follow-up on specified issues from the 2015 expert meetings 25-26 April 2016, Wollongong, Australia

[4] Expert meeting for Technical Assessment of IPCC Inventory Guidelines (Cross-sectoral issues) 27-29 April 2016, Wollongong, Australia

3 COVERAGE OF THE 2019 REFINEMENT

The *2019 Refinement* covers all IPCC inventory sectors but refinements are included for only those categories where the science was considered to have sufficiently advanced since 2006 or where new or additional guidance was required. The specific categories that have been refined through this process were selected through a technical assessment carried out in 2015 and 2016 and a subsequent scoping meeting held in August 2016 using the significance and prioritization criteria shown in Box 1.

BOX 1
SIGNIFICANCE AND PRIORITIZATION CRITERIA

- Significance of the source/sink and the gas within the sector on a global scale. Sources significant only for a limited number of particular countries, currently or in the foreseeable future, may not meet this criterion. The adequacy of the existing guidance for a particular category should be considered, as should the likelihood that new information would lead to a definite improvement in the IPCC Guidelines.
- Availability of relevant new scientific results.
- Sufficient data availability and maturity of scientific advances since 2006 to provide a basis for methodological development or refinement, including (1) ability to develop new or updated default emission/removal factors; and (2) feasibility of obtaining the necessary data to implement the methods.
- Emergence of new sources or gases meeting these criteria.

The outline of the *2019 Refinement* adopted by the IPCC was developed on the basis of the categories selected through the process mentioned above. However, the IPCC also agreed on the following principles when the outline was adopted.

- Authors should develop modifications even for those Chapters/Sections/Subsections where "No refinement" is indicated in the approved table of contents, if deemed necessary to ensure consistency with the refinements made in the other Chapters/Sections/Subsections.
- Authors may conclude no refinement should be made even for the Chapters/Sections/Subsections where refinement is expected in this approved table of contents, after comprehensive review of available literature.

In addition to the greenhouse gases included in the *2006 IPCC Guidelines*, the *2019 Refinement* includes gases for which global warming potential (GWP) values are given in one of the subsequent IPCC Assessment Reports (e.g., the Fourth or Fifth Assessment Report), unless the gases are covered by Annexes A through E of the Montreal Protocol. (Annex F of the Montreal Protocol lists hydrofluorocarbons, which are included in the *2019 Refinement*.) The *2019 Refinement* also provides estimation methods for halogenated greenhouse gases for which GWP values were not available from IPCC Assessment Reports at the time the *2019 Refinement* was developed. (See Volume 1, Chapter 8 and Volume 3, Chapters 6, 7, and 8 for examples of both sets of gases.)

The *2006 IPCC 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. The *2019 Refinement* follows this approach, and does not provide methods for the estimation of emissions of tropospheric precursors.

The structure of the *2019 Refinement* is the same as that of the *2006 IPCC Guidelines* so as to make it easier for inventory compilers to use the *2019 Refinement* with the *2006 IPCC Guidelines*. It comprises an Overview Chapter (this chapter) and the following five volumes.

- Volume 1: General Guidance and Reporting
- Volume 2: Energy
- Volume 3: Industrial Processes and Product Use
- Volume 4: Agriculture, Forestry and Other Land Use
- Volume 5: Waste

Across all the volumes, some additional sections have been included. The guidance focuses on inventory methodologies rather than on scientific discussions of the background material, for which references are provided.

4 RELATIONSHIP WITH THE 2006 IPCC GUIDELINES

As stated in Section 1 above, the *2019 Refinement* does not revise the *2006 IPCC Guidelines*, but updates, supplements and/or elaborates the *2006 IPCC Guidelines* where gaps or out-of-date science have been identified. It does not replace the *2006 IPCC Guidelines*, but should be used in conjunction with the *2006 IPCC Guidelines* and the *Wetlands Supplement*.[5]

In order to clarify the relationship with the guidance given in the *2006 IPCC Guidelines*, the *2019 Refinement* indicates the type of refinement provided where a refinement is implemented. The types of refinement are defined in Table 1.

TABLE 1
DEFINITION OF TYPES OF REFINEMENT

Type of refinement	Explanation
Update	This is to update existing guidance (table, section, or an entire chapter) in the *2006 IPCC Guidelines* to address the needs explained in the first or second bullet in Section 1 (Introduction) of this chapter. New elements that do not change default approaches in the existing guidance is considered "update". A typical example is to provide new default values for EFs contained in a table in the *2006 IPCC Guidelines*, and in this case it is considered "Update of Table X.X (on default EFs)". When updating a section or an entire chapter, in some cases these sections or chapters have been entirely rewritten when it was difficult to provide only the new information without overlapping with the existing guidance. From the inventory compiler's view point, "update" of existing guidance means that they are encouraged to use the table/section/chapter in the *2019 Refinement* **instead of** the corresponding table/section/chapter in the *2006 IPCC Guidelines*.
Elaboration	This is to elaborate existing guidance in the *2006 IPCC Guidelines* to address the needs explained in the first or third bullet of Section 1 (Introduction) of this chapter. New elements that may be added to default approaches in the existing guidance are considered "elaboration". Also, additional or alternative up-to-date information and guidance provided to clarify existing guidance are considered "elaboration". Elaboration of a section or entire chapter does not require a rewrite of an existing section or chapter, but rather the provision of a sub-section or section that contains additional or alternative up-to-date information without overlap with existing guidance. From the inventory compiler's view point, "elaboration" of existing guidance means that they are encouraged to use the table/section/chapter in the *2019 Refinement* **in conjunction with** the corresponding table/section/chapter in the *2006 IPCC Guidelines*.
New guidance	This is to add completely new guidance on issues for which there is essentially no guidance in the *2006 IPCC Guidelines* to address the needs explained in the first bullet in Section 1 (Introduction) of this chapter. Creation of default approaches to issues that are not well covered in the *2006 IPCC Guidelines* is considered "new guidance". From the inventory compiler's view point, "new guidance" means that they are encouraged to use the section/chapter in the *2019 Refinement* **without reference to** specific sections/chapters in the *2006 IPCC Guidelines*, recognizing that there is essentially no corresponding guidance in the *2006 IPCC Guidelines*.
No refinement	This means that no refinement has been made in that section.

With a view to helping inventory compilers understand the relationship between the *2019 Refinement* and the *2006 IPCC Guidelines*, each volume has an annex titled "Mapping table for the *2019 Refinement* to the *2006 IPCC*

[5] The IPCC decided to produce the *2019 Refinement* as a separate Methodology Report which should be used in conjunction with the *2006 IPCC Guidelines*. Consolidating all methodological guidance into a single Methodology Report would require a new decision by the IPCC.

Guidelines". This annex in each volume provides a road map for relating sections, equations, tables, figures and boxes in the *2019 Refinement* to the *2006 IPCC Guidelines*.

BOX 2
EXAMPLE OF MAPPING TABLE FOR THE 2019 REFINEMENT TO THE 2006 IPCC GUIDELINES (VOL.1)

Section Title	Type of Refinement	2006 Guidelines Section Number	2019 Refinement Section Number
Chapter 1			
Concepts	U	1.1	1.1
National Inventory Management Systems	NG	NA	1.5
Chapter 2			
Introduction	NG	2.1	2.1
Collecting data	NG	2.2	2.2
Use of Facility Data in Inventories	NG	2.3	2.3
General guidance on performing surveys	E	Annex 2A2	Annex 2A2
Chapter 3			

U = Update, NG = New Guidance, E = Elaboration

The *2019 Refinement* retains the definition of *good practice* that is used in the *2006 IPCC Guidelines*[6]. This definition has gained general acceptance amongst countries as the basis for inventory development. According to this definition, national inventories of anthropogenic greenhouse gas emissions and removals 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.*

These requirements are intended to ensure that estimates of anthropogenic emissions by sources and removals by sinks, even if uncertain, are *bona fide* estimates, in the sense of not containing any biases that could have been identified and eliminated, and that uncertainties have been reduced as far as practicable, given national circumstances. Estimates of this type are presumably the best attainable, given current scientific knowledge and available resources. The *2019 Refinement* also recognises the principles of transparency, accuracy, completeness, consistency and comparability defined in the *2006 IPCC Guidelines*.

The *2006 IPCC Guidelines* are intended to help prepare national inventories of anthropogenic emissions by sources and removals by sinks. Nonetheless, the Guidelines can also be relevant for estimating actual emissions or removals at the subnational, entity or project level. This is the case also with the *2019 Refinement.* Some examples of the use of the guidance in the *2006 IPCC Guidelines* and/or the *2019 Refinement* for other purposes than national inventory preparation are provided in some boxes in the *2019 Refinement.*

[6] The definition was originally introduced with the *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* published in 2000.

5 SPECIFIC DEVELOPMENTS IN THE 2019 REFINEMENT

The *2019 Refinement* contains the following specific developments, among others, since the *2006 IPCC Guidelines*:

Volume 1 (*General Guidance and Reporting*)

- *National greenhouse gas inventory arrangements*: The *2019 Refinement* elaborates guidance on establishing greenhouse gas inventory arrangements to support the development, improvement and maintenance of national greenhouse gas inventories. This guidance is not deigned to be prescriptive given that the shape and form of greenhouse gas inventory arrangements depends on national circumstances. Instead, the guidance provides approaches and examples of national greenhouse gas inventory arrangements that could be useful. In addition, institutional arrangements include the interactions between organisations that are involved with the greenhouse gas inventory inputs, compilation processes, and outputs.

- *Data collection strategy*: General guidance for collecting existing national/international data and new data are elaborated. The material can be used by both countries establishing a data collection strategy for the first time and countries with established data collection procedures. It has also the advantage to be applicable to emission factor, activity, and uncertainty data collection. *Use of facility-level data in inventories*: Detailed industrial facility-level data that are increasingly collected for various goals such as tracking the progress of emission trading programmes or climate change policies has the potential to be utilized in national greenhouse gas inventories. The challenge for inventory compilers is assessing how best to integrate facility reported data to achieve improvements, especially if there are some outstanding coverage and completeness issues. The *2019 Refinement* includes new guidance on how best to use facility-level data that is not originally designed for national greenhouse gas inventory compilation. A new decision tree for selecting facility-level data is provided as well as *good practice* reporting considerations associated with facility-level data used in the national greenhouse gas inventory.

- *Uncertainty analysis*: The *2019 Refinement* provides an update on uncertainties associated with activity data. It also incorporates guidance on how to derive uncertainty estimates from activity data generated based on random samples. This elaborated guidance has useful applications particularly in the AFOLU sector in dealing with uncertainty estimates from land use surveys or forest cover surveys. The updated guidance also includes key requirements for use of Approach 1 uncertainty analysis with examples. A practical step-by-step example demonstrating the use of Approach 2 uncertainty analysis (Monte-Carlo analysis) is also provided to guide inventory compilers.

- *Key category analysis*: General principles and guidance are updated and an updated trend approach is described. Priorities for maintenance and improvement of the inventory are addressed, and new guidance in determining the appropriate level of disaggregation of greenhouse gas estimates to identify key categories is provided.

- *Comparison with atmospheric measurements*: Guidance on comparison of greenhouse gas emission estimates with atmospheric measurement has been updated and elaborated to reflect the state of science for atmospheric measurements and their application to verifying national emissions. The most notable advances were achieved in the application of inverse models of atmospheric transport for emission estimates at the national scale. Thus, atmospheric measurements are being used to provide useful quality assurance of the national greenhouse gas emission estimates. The guidance highlights key components and necessary steps needed for national greenhouse gas inventory verification using atmospheric measurements.

- *Use and reporting of models*: The *2019 Refinement* provides new guidance on complete and systematic use and reporting models. A typical model development/selection process is provided with a checklist for ensuring *good practice* in the use of complex, higher tier models in national greenhouse gas inventories

- *Non-linear interpolation*: New methodology with an example has been provided in the *2019 Refinement* on non-linear interpolation analysis. This is relevant in cases where time series consistency is best represented by multiplicative (exponential) rather than additive (linear) relationships.

Volume 2 (*Energy*)

- *Fugitive emissions from mining, processing, storage and transportation of coal*: The *2019 Refinement* includes guidance on emissions from exploration, and on carbon dioxide (CO_2) emissions from underground mines.

- *Fugitive emissions from oil and natural gas systems*: The *2019 Refinement* includes emission factors representative for current practice, additional guidance for unconventional oil and gas production, and methods and emission factors for abandoned wells.

- *Fuel transformation*: The *2019 Refinement* includes new section on fuel transformation, such as charcoal production, coke production, biomass transformation processes and gasification transformation processes.

Volume 3 (*Industrial Processes and Product Use*)

- *New categories and new gases*: The *2019 Refinement* expands the scope of the *2006 IPCC Guidelines* to include more manufacturing sectors identified as sources of greenhouse gases. These include production of hydrogen, rare earth metals, and alumina, and waterproofing of circuit boards. In addition, a basis for future methodological development is provided for fluorinated treatment of textiles, carpet, leather and paper. Additional greenhouse gases identified in the IPCC Fourth and Fifth Assessment Reports, as well as other references, are also included where anthropogenic sources have been identified. Greenhouse gases identified in the IPCC Fourth and Fifth Assessment Reports include, for example, additional hydrofluorocarbons, perfluorocarbons, and halogenated ethers, such as PFPMIE (a perfluoropolyether widely used as a heat transfer fluid in electronics manufacturing).

- *Updates and elaborations*: The guidance for several source categories has been updated and elaborated. This includes the guidance for production of nitric acid, fluorochemicals, iron and steel, aluminum, and electronics, and for the production and use of refrigeration and air-conditioning equipment.

Volume 4 (*Agriculture, Forestry and Other Land Use*)

- *Interannual variability (IAV)*: A new section has been introduced to provide an option that may be used to disaggregate Managed Land Proxy (MLP) emissions and removals into those that are considered to result from human effects and those that are considered to result from natural effects. These approaches may be of interest to countries with AFOLU sector emissions that have high IAV due to natural effects. The section first addresses definitional issues, followed by a description of whether or not different methodological approaches used to estimate C stock changes quantify the interannual variability of emissions and removals. A generic methodology to estimate, disaggregate and report the contribution of natural disturbances to the emissions and removals on managed lands is then provided, along with country-specific examples of approaches to disaggregating anthropogenic and natural effects on managed lands. The purpose of this guidance is to support countries that wish to increase the transparency of anthropogenic greenhouse gas flux estimates on managed lands.

- *Harvested wood products (HWPs)*: The methods and equations in the *2006 IPCC Guidelines* have been updated. The updated methods and equations better help inventory compilers to include the HWP pool estimates in greenhouse gas inventories using any of the three approaches: 'stock-change' approach, 'production' approach and 'atmospheric flow' approach[7].

- *Biomass estimates*: Biomass Tier 1 factors have been updated for Forest Lands, Croplands and Settlements. New sections on Tier 2 guidance for the use of allometric equations and biomass maps are introduced.

- *Flooded Lands*: New guidance is provided for CO_2 and non-CO_2 emissions from *Land Converted to Flooded Lands* and non-CO_2 emissions from *Flooded Land Remaining Flooded Land*. Methods for future development associated with these sources were included in Appendix 2 and Appendix 3 of Chapter 7, Volume 4 of the *2006 IPCC Guidelines*. The science has matured over the past decade and these sources are now included in the main guidance (instead of appendices) of Chapter 7, Volume 4 of the *2019 Refinement* for a more complete inventory of greenhouse gas emissions from managed lands.

- *Soil carbon:* Tier 1 emission factors have been updated for tillage and land use based on evolving understanding of management impacts on soils. Many of the updated factors reflect a smaller impact of anthropogenic activity on soil C than default factors provided in the *2006 IPCC Guidelines*.

- *Soil nitrous oxide (N_2O)*: Tier 1 estimates have been updated based on the latest science for direct and indirect emissions. A key development is the disaggregation of emission factors by climate region.

- *Livestock and manure management*: Tier 1 emission factors have been updated considering updated productivity data and integrating differential emission factors and for high and low productivity systems. Tier 1 method to estimate methane (CH_4) emissions from manure management has been updated for consistency with N_2O emissions.

Volume 5 (*Waste*)

- *Waste generation, composition and management*: The *2019 Refinement* updates key parameters used in FOD method include waste generation rate and waste composition by countries and region using UN classification

[7] At the time the *2019 Refinement* was developed, these approaches were under discussion within the UNFCCC process in the context of revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention.

were updated in the comparable year (2010) and provides default value and uncertainty of carbon content, nitrogen content and DOC of domestic and industrial sludge in percent of dry matter.

- *Estimation of CH_4 emission from landfill*: Guidance on the use of methane collection factor (MCF) in different management conditions of solid waste disposal sites (SWDS) is updated. Choice of emission factors and parameters include MCF to estimate CH_4 emission from active aeration landfill have been provided by level of landfill management (poorly and well managed). Spreadsheet of waste model has been updated accordingly to the refinement. Elaboration and updating of default values of fraction of degradable organic carbon which decomposes (DOC_f) for different waste components based on waste components analysed and its uncertainty are provided.

- *Incineration and open burning of waste*: Guidance on emission estimation from new technologies include gasification and pyrolysis has been elaborated with provision of CH_4 and N_2O emission factors to ensure a more complete coverage of sources. Oxidation factor of MSW open burning is updated.

- *CH_4 emissions from wastewater treatment*: Updated guidance is provided for the estimation of CH_4 from wastewater treatment, and updated emission factors for septic systems and centralised wastewater treatment plants are provided. Updated emission factors are also provided for CH_4 emissions from wastewater after disposal of untreated wastewater or wastewater treatment effluent into aquatic environments.

- *N_2O emissions from wastewater treatment*: New guidance and emission factors are provided for N_2O emissions from domestic and industrial wastewater treatment plants, and updated emission factors are provided for N_2O emissions from wastewater after disposal of untreated wastewater or wastewater treatment effluent into aquatic environments.

- *Abiogenic (fossil) CO_2 emissions from wastewater treatment and discharge*: A discussion of abiogenic (fossil) CO_2 emissions from wastewater treatment and discharge, where fossil organic carbon is present in wastewater or treatment sludge is presented.

- *Discharge into aquatic environments*: An alternate set of emission factors is provided for CH_4 and N_2O emissions from wastewater after disposal of untreated wastewater or wastewater treatment effluent into aquatic environments when the country has activity data to differentiate the conditions of the waterbody receiving the discharge.

6 CLARIFICATION ON KEY CONCEPTS IN THE 2019 REFINEMENT

The following key concepts should be noted when using the *2019 Refinement*. These are consistent with the *2006 IPCC Guidelines*.

- The *2019 Refinement* provides guidance for data gathering, compilation, and reporting. Reporting refers to the presentation of emission inventory estimates in tables or other formats used to communicate inventory information. The *2019 Refinement* does not provide guidance for reporting of information used to assess compliance with commitments.
- Reporting tables are provided in Volume 1 as part of general guidance for reporting. They are not intended to prescribe specific reporting formats under the UNFCCC that should be developed and agreed by the Parties to the UNFCCC.
- The *2019 Refinement* provides methods for estimating emissions (and removals as appropriate) for each gas in mass units. It does not recommend any specific metrics (e.g., GWP values) to calculate emission estimates in CO_2 equivalent units. Some guidance included in the *2019 Refinement* (e.g., key category analysis) suggests calculation of emission estimates in CO_2 equivalent, for which any metrics can be used.