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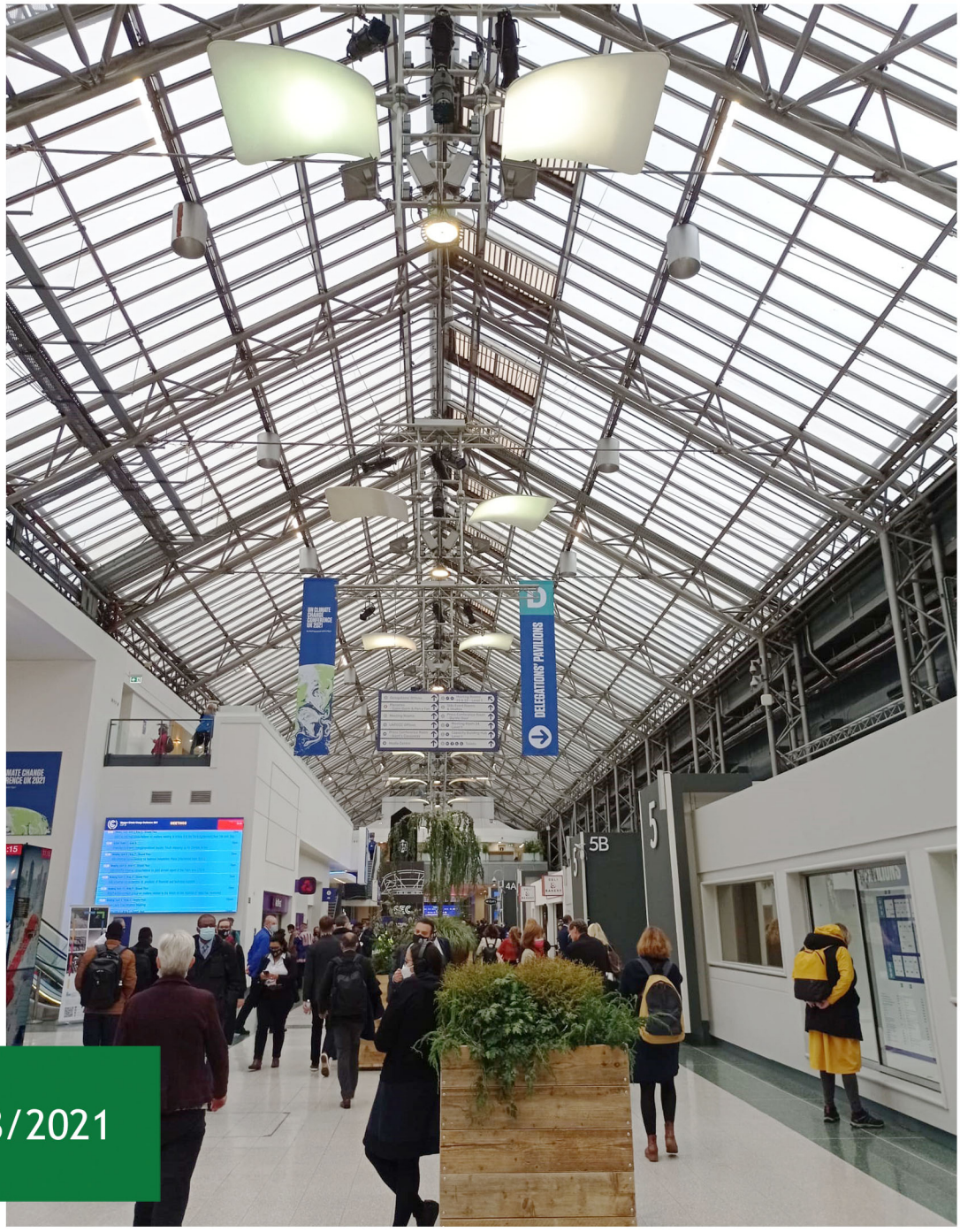
RAPPORTI

# Moving to the 2006 IPCC guidelines for UNFCCC reporting

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Rapporti 358/2021

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# OVERVIEW

In the framework of the international climate negotiations under the United Nations Framework Convention on Climate Change (UNFCCC), transparency arrangements play an essential role. Information gathered are critical to driving the increased action required to meet the goal of limiting global warming to well below 2 degrees, pursuing efforts to 1.5, as well as to build confidence in the system and mutual trust among nations.

With the adoption of the Paris Agreement, a new Enhanced Transparency Framework (ETF) was established, with common rules applicable to all Parties and the provision of specific flexibilities for those developing countries that need them in light of their capacities.

The ETF is crucial for the implementation of the Paris Agreement, providing the foundations for monitoring, reporting, and review of information while ensuring a common system that facilitates ambition and improvements over time.

At COP24, the Modalities, Procedures and Guidelines (MPGs) for the ETF were adopted as part of the Paris Rulebook, containing the rules and requirements applicable to all countries for effective implementation of the ETF. Specifically, Parties will be required to submit a Biennial Transparency Report (BTR) every two years, including a greenhouse gas inventory of emissions and removals (GHGI) in case it was not submitted as a standalone report. In this context, the 2006 IPCC guidelines were adopted as mandatory reporting guidelines to be used by all Parties in elaborating their GHGI, which represent a key component of the ETF.

At COP26, the new common reporting tables (CRTs) to report GHGIs under the Paris Agreement have been adopted[1], and a new reporting software will be developed accordingly by the UNFCCC Secretariat by June 2024.

At the international level, the use of these new reporting tables and software will pose challenges to developing countries, most of which have generally limited experience in using the 2006 IPCC Guidelines as well as in using a software for reporting. Moreover, it should be noted that differences exist in the structure of the 2006 IPCC Guidelines and the structure of reporting tables, thus potentially increasing the need for training and capacity-building support.

To contribute addressing some of the challenges outlined above, this report aims to assist developing countries in moving towards the 2006 IPCC Guidelines to prepare meeting the new reporting requirements of the Paris Agreement. To this end, the report makes an analysis of the changes occurred in the 2006 IPCC guidelines compared to the previous ones, while providing suggestions on how to undertake UNFCCC reporting through the Common Reporting Tables (CRTs) that all Parties will have to use in the new transparency regime.

This report is structured along four modules: 1) Energy, 2) Industrial Processes and Product Use (IPPU), 3) Agriculture, Forestry and Other Land Use (AFOLU) and 4) Waste. Each module is further organized by reporting categories agreed upon in the new CRTs, with the view of facilitating the ultimate goal of improving clarity in reporting.

Each module only analyses the most relevant changes that occurred between the 1996 IPCC Guidelines (and other guidelines) and the 2006 IPCC Guidelines. It therefore focuses on the changes, rather than the substance of the guidelines. Nevertheless, some further details are provided in particular for the AFOLU sectors, since there were significant changes both in contents and structure, by focusing on both Agriculture and LULUCF.

For each category, summary tables are presented to show the changes and correspondence in the reporting structure, both between the 1996 IPCC Guidelines and the 2006 IPCC Guidelines, and between the 2006 IPCC Guidelines and the CRT categories.

Across the modules, several boxes labelled as “suggestions and remarks from experts” are presented, representing suggestions from experts based on their experience and expertise. Such boxes refer both to reporting tips and to improvements that were made in the 2019 Refinement. Indeed, while the Refinement was not yet adopted by the CMA and its application is still voluntary, as noted by the outcomes of COP26[2], in several cases the application of refinements made would significantly facilitate reporting or improve its transparency.

[1] The Common Reporting Tables adopted by the CMA are available here: https://unfccc.int/documents/311076

[2] Decision 5/CMA.3 *“notes that Parties may use on a voluntary basis the Intergovernmental Panel on Climate Change 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories”.*

# PREMESSA (Italian)

Nell'ambito dei negoziati internazionali sul clima della Convenzione Quadro delle Nazioni Unite sui Cambiamenti Climatici (UNFCCC), la trasparenza relativa alla rendicontazione delle emissioni di gas serra ed al monitoraggio delle azioni dei Paesi riveste un ruolo essenziale. Le informazioni raccolte e trasmesse sono fondamentali per guidare le politiche necessarie per raggiungere l'obiettivo di limitare il riscaldamento globale ben al di sotto dei 2 gradi, perseguendo sforzi per mantenerlo al di sotto degli 1,5°C, nonché per accrescere la fiducia nel sistema e nelle azioni reciproche tra i Paesi.
Con l'adozione dell'Accordo di Parigi, è stato istituito un nuovo quadro di trasparenza rafforzato (ETF), con regole comuni applicabili a tutte i Paesi e la previsione di flessibilità specifiche per quei Paesi in via di sviluppo che ne hanno bisogno in virtù delle proprie capacità.
L'ETF è fondamentale per l'attuazione dell'Accordo di Parigi, poiché fornisce le basi per il monitoraggio, la rendicontazione e la revisione delle informazioni, garantendo allo stesso tempo un sistema comune che faciliti l'ambizione e i miglioramenti nel tempo.
Alla COP24, le modalità, le procedure e le linee guida (MPG) per l'ETF sono state adottate come parte del *Paris Rulebook*, contenente le regole e i requisiti a cui tutti i paesi dovranno attenersi. In particolare, le Parti saranno tenute a presentare un Rapporto biennale sulla trasparenza (BTR) ogni due anni, che includa un inventario degli assorbimenti e delle emissioni di gas serra (GHGI) nel caso in cui non sia stato presentato come rapporto autonomo. In questo contesto, le linee guida IPCC del 2006 '*2006 IPCC Guidelines*' sono state adottate come linee guida obbligatorie per tutte i Paesi nell'elaborazione dei propri inventari, che rappresentano una componente chiave dell'ETF.
Alla COP26, sono state adottate le nuove tabelle comuni (CRT) per la rendicontazione delle emissioni e degli assorbimenti di gas serra da utilizzare nell'ambito dell'Accordo di Parigi, ed entro il giugno 2024 sarà sviluppato un nuovo software per la loro trasmissione elettronica.
A livello internazionale, l'uso di queste nuove tabelle e del futuro software di rendicontazione porrà delle sfide ai Paesi in via di sviluppo, la maggior parte dei quali ha ad oggi un'esperienza limitata nell'uso delle Linee guida '*2006 IPCC Guidelines*' e nell'uso di un software per la rendicontazione. Inoltre, le differenze tra la struttura delle Linee guida '*2006 IPCC Guidelines*' e quella delle tabelle di rendicontazione UNFCCC accrescono ulteriormente le necessità di supporto tecnico nei Paesi in via di sviluppo.
Per contribuire ad affrontare alcune delle sfide sopra delineate, questo rapporto ha lo scopo di assistere i Paesi in via di sviluppo nell'implementazione delle Linee guida '2006 IPCC Guidelines', in modo da poter soddisfare i nuovi requisiti di rendicontazione dell'Accordo di Parigi. A tal fine, il rapporto analizza i cambiamenti occorsi nelle Linee Guida '*2006 IPCC Guidelines*' rispetto alle precedenti, fornendo suggerimenti su come intraprendere la rendicontazione dell'UNFCCC attraverso le nuove tabelle "CRT", che dovranno essere utilizzare da tutti i Paesi.

Questo rapporto è strutturato in quattro moduli: 1) Energia, 2) Processi industriali e usi di prodotto (IPPU), 3) Agricoltura, silvicoltura e altri usi del suolo (AFOLU) e 4) Rifiuti. Ciascun modulo è ulteriormente suddiviso secondo le categorie di reporting delle nuove tabelle "CRT", nell'ottica di facilitare le attività di rendicontazione dei Paesi.
Ciascun modulo analizza i cambiamenti più rilevanti avvenuti tra le Linee guida IPCC 1996 (e altre linee guida) e le Linee guida '*2006 IPCC Guidelines*', focalizzandosi su come implementare le modifiche metodologiche di queste ultime. Per i settori AFOLU, sono stati forniti ulteriori dettagli, viste le profonde modifiche metodologiche occorse ai settori Agricoltura e LULUCF.
Per ogni categoria, sono presentate tabelle riepilogative che riportano le modifiche e la corrispondenza nella struttura di reporting, sia tra le Linee guida IPCC 1996 e le Linee guida '*2006 IPCC Guidelines*', sia tra le Linee guida '*2006 IPCC Guidelines*' e le categorie delle nuove tabelle "CRT".
Nei diversi moduli, sono inclusi dei box con "suggerimenti e osservazioni di esperti", basati sulla loro esperienza e conoscenza dei diversi settori. Tali box includono sia suggerimenti pratici per supportare e guidare le azioni di rendicontazione, sia indicazioni circa i miglioramenti apportati nel '*IPCC 2019 Refinement'*. Infatti, sebbene il *2019 Refinement* non sia stato ancora adottato dalla Conferenza delle Parti ai sensi dell'Accordo di Parigi (CMA) e la sua applicazione sia ancora volontaria, come notato dalle decisioni di Glasgow[3], in alcuni casi i perfezionamenti apportati facilitano significativamente la rendicontazione o ne migliorano la trasparenza.

[3] Decisione 5/CMA.3

# 1 ENERGY

## Overview

For the Energy sector, the scope of the 2006 IPCC Guidelines generally corresponds to the 1996 IPCC Guidelines, with a general improvement in the structure of chapters and the description of methodologies. In the new guidelines, the tiers approach is retained from the 1996 ones, with some improvements and more detailed decision trees for the selection of tiers. More detailed information is generally provided on how to discriminate between process emissions to be reported in the IPPU sector and energy emissions to be included in the Energy sector.

Under "Fuel Combustion" (1.A), some new subcategories were added or further disaggregated, and others were further detailed. Under "Fugitive Emissions" (1.B), some reporting subcategories were consolidated, and some new ones were added. A new category "Carbon Dioxide Transport and Storage" (1.C) was also added, to cover emissions from carbon capture and storage activities.

The 2006 IPCC Guidelines lead to some quantitative implications for countries' national inventories, as well as several implications for reporting of emissions. Emission factors and parameters were largely updated, therefore countries using IPCC default values will have to incorporate the new values in their emissions inventory and to apply them consistently over the time series; to this purpose, guidance is available on how to ensure time series consistency. Moreover, further information is provided and a revised organization was applied with respect to the definition of fuel types, to avoid double counting between the energy and other sectors and for Quality Assurance / Quality Control (QA/QC). The number of fuels, non-fuel uses and activities to be considered also generally increased compared to the 1996 IPCC Guidelines (e.g., extended list of biogenic fuels, or non-fuel uses to be excluded in the reference approach).

Such changes, along with the refinement and introduction of new categories will require additional effort for collecting the data and for ensuring a consistent dataset throughout the whole time series. In practical terms, changes could potentially lead to increased emissions estimates, when the corresponding activity was not reported before, or to changes in the allocation of emissions across subcategories (while not necessarily affecting totals). However, implications will significantly differ between countries based on their starting points and national circumstances.
Furthermore, the 2006 IPCC Guidelines provide an approach to estimating indirect $CO_2$ emissions from the oxidation of non-$CO_2$ gases, for instance for fossil fuel combustion activities; as well as an approach for estimating $N_2O$ emissions that originate from all significant sources of nitrogen deposition, while in the previous guidelines this was limited to a smaller list of sources. Such improvements are also reflected in the current countries reporting framework for Annex I countries, reported as additional memo items.

Finally, under all categories, stronger focus and updated guidance is offered around assessment of completeness, assessment of uncertainty and procedures to conduct QA/QC, targeting both $CO_2$ and non-$CO_2$ emissions.

**Box 1.1** – *Summary of main improvements from the 1996 to the 2006 IPCC Guidelines for the Energy sector*

| **MAIN SPECIFIC IMPROVEMENTS ACROSS THE ENERGY SECTOR** | |
|---|---|
| Added: | - New category for treatment of $CO_2$ capture and storage (CCS).<br>- New subcategories for $CH_4$ from abandoned coal mines (a methodology is included for the first time), flaring or drained methane, uncontrolled combustion and burning of coal deposits.<br>- New subcategory for catalytic converters using urea (new category under road transport). |
| Revised: | - Refinement of methodologies and improvement of guidance.<br>- Consolidation and/or disaggregation of subcategories.<br>- Default oxidation coefficients of $CO_2$ and default emission factors. |

## 1.1 Fuel Combustion (1.A)

### *1.1.1 Overarching changes*

In the 2006 IPCC Guidelines, the methodology for estimating emissions from **"Fuel combustion" (1.A)** generally follows the same principle as in the previous guidelines and is structured along two

main subsets of guidelines dealing with "stationary" and "mobile" sources of combustion. A detailed tabular, sectoral split for stationary and mobile combustion is provided in the description of sources (Table 2.1 and Table 3.1.1, respectively).

**Stationary combustion** mainly concerns the following categories:
- **"Energy industries" (1.A.1)**, including all related subcategories;
- **"Manufacturing industries and construction" (1.A.2)**, including all related subcategories;
- **"Other sectors" (1.A.4)**, including all related subcategories with the exception of components falling under "mobile", i.e. "Off-road Vehicles and Other Machinery" (1.A.4.c.ii) and "Fishing" (1.A.4.c.iii);
- **"Non specified" (1.A.5)**, specifically the "Stationary" subcategory (1.A.5.a).

In relation to **mobile combustion**, instead, the following categories are concerned:
- **"Transport" (1.A.3)**, including all related subcategories;
- **"Other sectors" (1.A.4)**, specifically "Off-road Vehicles and Other Machinery" (1.A.4.c.ii) and "Fishing (mobile combustion)" (1.A.4.c.iii)
- **"Non specified" (1.A.5)**, specifically "Non-specified mobile" (1.A.5.b).

In the 2006 IPCC Guidelines, a generalised decision tree for estimating emissions from fuel combustion was added, providing clear indications for the selection of the appropriate Tier approach.
A further significant change lies on the assumption of a complete combustion: **full oxidation of fuel is assumed** for the derivation of default emission factors for fuel combustion, for all fuels (fraction of carbon oxidized equals 1). In the 1996 IPCC Guidelines, the oxidation factors were 0.98 for coal, 0.99 for oil and peat, and 0.995 for gas; this change therefore leads to an increase of $CO_2$ emission factors in the 2006 IPCC Guidelines of approximately 2 % for coal, 1 % for oil and peat and 0.5 % for gas compared to the old guidelines. Nevertheless, the 2006 IPCC Guidelines allow for differentiated oxidation factors for higher tier $CO_2$ emission factors.

Moreover, **$CO_2$, $CH_4$ and $N_2O$ emission factors** are now provided based on the default carbon contents with upper and lower limits, with the lists being updated and/or extended for some fuels in comparison with the previous guidelines. In particular, default emission factors for stationary combustion have been revised or introduced for fuels such as derived gases, biofuels, coke, gasoline, anthracite and wood waste. Detailed references for changes affecting specific subcategories are available in the respective paragraphs. This results in changes of the effective $CO_2$ emission factors for countries that use default emission factors. Moreover, an updated and extended set of **net calorific values (NCVs)** are provided, including default NCVs for fuels for which only country-specific values were available in the 1996 IPCC Guidelines, as well as their upper and lower limits of the 95% confidence interval. Several new NCVs were introduced, especially for derived gases, waste fuels and biogenic fuels. The quantitative impact on countries' inventories is expected to be small, since changes in comparison to the 1996 IPCC Guidelines are only moderate.

Regarding the selection of emission factors, explicit reference is made to the IPCC Emission Factor Database (EFDB)[4] where country-specific and regional emission factors are provided. A detailed description of different fuel types is now available in the 2006 IPCC Guidelines including the definition of several biogenic fuels. Furthermore, **Tier 3** now explicitly mentions continuous emissions monitoring (CEM) as a way to collect useful information to estimate emissions, since plant-specific data on $CO_2$ emissions are increasingly available. This is also reflected in modifications of the decision tree included in the 2006 IPCC Guidelines, which is useful to select the appropriate tier to be used according to available information in the country.

In the 2006 IPCC Guidelines, **$CO_2$ emissions from non-fuel use of fossil fuels** were entirely moved from the Energy Sector (under which they were located in the IPCC 1996 Guidelines) to the IPPU sector. Furthermore, detailed guidance is available on avoiding double counting of activity data between the Energy sector and other sectors.

The **Reference Approach** in the 2006 IPCC Guidelines did not significantly change compared to the 1996 IPCC Guidelines, but some clarifications and further descriptions have been included (e.g. "Carbon stored" is now covered under "Carbon excluded"), as well as a detailed description of

[4] https://www.ipcc-nggip.iges.or.jp/EFDB/main.php

feedstocks, reductants, and non-energy products. As in the sectoral approach, full oxidation should generally be assumed, unless country-specific information is available. Arguments on the differences between the sectoral and the reference approach are also provided.

**Box 1.2** – *Treatment of biomass*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Treatment of biomass**

In the 2019 Refinement, the treatment of biomass was further discussed: there is an expected increase in the attention for biomass worldwide as countries are moving towards low-emission pathways, which involve an enhanced use of biofuels. This may have specific implications for emissions from charcoal production, biochar production, transformation processes (biomass to liquids, biomass to gas and wood pellet production). The overall IPCC approach to greenhouse gas emissions from combustion of biomass or biomass-based products at the national level allows for complete coverage of emissions and sinks, and involves all IPCC sectors, including, in particular, Energy, Agriculture, Forestry and Other Land-Use (AFOLU) and Waste.

### *1.1.2 Energy industries (1.A.1)*

In the shift from the 1996 to the 2006 IPCC Guidelines, the **"Energy Industries" subcategory (1.A.1)** experienced both structural and methodological changes.

Compared to the 1996 IPCC Guidelines, a number of subcategories were further disaggregated.

Subcategory "Main Activity Electricity and Heat Production" (1.A.1.a) now features three subcategories:

- **"Electricity Generation" (1.A.1.a.i);**
- **"Combined Heat and Power Generation (CHP)" (1.A.1.a.ii);**
- **"Heat Plants" (1.A.1.a.iii).**

Similarly, subcategory "Manufacture of Solid Fuels and Other Energy Industries" (1.A.1.c) now features two subcategories:

- **"Manufacture of Solid Fuels" (1.A.1.c.i);**
- **"Other Energy Industries" (1.A.1.c.ii).**

As one of the subcategories most affected by changes in methods for **stationary combustion** sources, the 2006 IPCC Guidelines have introduced changes for the estimation of GHG emissions from Energy Industries, in particular for non-$CO_2$ greenhouse gas emissions. Specifically, a new approach for estimating the fuel consumption for technologies in the Tier 3 approach based on technology penetration has been introduced. The fuel consumption is then determined by multiplying the fuel consumption in the source category concerned with a fraction of penetration of the corresponding technology in the source category, which may be determined by output data (e.g. electricity production), differentiated by technology types.

For this subcategory, the 2006 IPCC Guidelines also introduced some changes involving **updated and extended emission factors**, which for $CO_2$ correspond to the ones provided for the whole energy sector. $CH_4$ and $N_2O$ emission factors are generally based on the 1996 IPCC Guidelines, with some revisions and additions; it should be noted that those factors apply to technologies without emission controls, thus possibly overestimating emissions. Default emission factors "assume effective combustion in high temperature" and "do not take into account the impact of start-ups, shutdowns or combustion with partial loads". For Tier 3 emissions estimation, the 2006 IPCC Guidelines include several lists of technology-specific and fuel-specific $CH_4$ and $N_2O$ emission factors for comparison or example purposes.

A detailed list of default emissions factors that have been introduced ("n") or revised ("r") in the "energy industries" subcategory is available in Table 2.2 of the 2006 IPCC Guidelines (Volume 2, Chapter 2 "Stationary Combustion").

**Box 1.3** – *Manufacture of solid fuels and other energy industries*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Manufacture of solid fuels and other energy industries**

The 2006 IPCC Guidelines do not provide guidance for emissions from charcoal production, while the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories do not contain guidance for closed furnace charcoal production. In the 2019 Refinement, there is a section on charcoal production (Volume 1, Chapter 4, §4.3.2.1) but references and EFs only refers to traditional combustion techniques and not to more advanced kilns.

If emissions from charcoal production are not estimated (for instance, in cases those emissions are kept at a minimum through the use of modern boilers), countries should use the notation key "NE" in reporting formats/tables and provide a justification for its use.

**Box 1.4** – *Avoiding double counting of carbon in steel and iron production*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Avoiding double counting of carbon in steel and iron production**

For the steel production, carbon plays the dual role of fuel and reductant. It is important not to double-count the carbon from the consumption of coke or other reducing agents if this is already accounted for as fuel consumption in the Energy Sector or, vice versa, if it is already accounted for in the IPPU sector. Coke is currently an essential element in the integrated steel production because, apart from being a reducing agent, it also serves as a carrier of the bulk column in the blast furnace. Without this carrying capacity, blast furnace operation would not be possible. The coke primarily serves as a reducing agent, but also as a fuel and it is not possible to split up in a realistic way between energy and process contributes. But it is possible, indeed mandatory, to avoid double counting. To achieve this goal it is necessary to realize a carbon balance considering all the inputs and the outputs of carbon in the system, in particular the coal used for coke production and the quantities of derived fuels used in various sectors. This can be complex because iron and steel production consists of many production processes (occurring at different facilities), such as coking, sintering, iron-making, blast furnace steelmaking and rolling. These processes are connected to each other with the pipeline network which carries by-product gases, such as coke oven gas, blast furnace gas and basic oxygen furnace gas. The first requisite to realize a good carbon balance is to have good energy statistics for the different energy carriers and therefore a reliable national energy balance.

### *1.1.3 Manufacturing industries and construction (1.A.2)*

Similarly to "Energy industries", the "**Manufacturing industries and construction**" subcategory (1.A.2) also featured changes in the reporting structure of GHG emissions, which in the 2006 IPCC Guidelines are disaggregated into more subcategories than before. Specifically, the "Other" subcategory in the 1996 IPCC Guidelines (previously 1.A.2.f) has now been replaced by the following additional subcategories:

- **"Food Processing, Beverages and Tobacco" (1.A.2.e);**
- **"Non-Metallic Minerals" (1.A.2.f);**
- **"Transport Equipment" (1.A.2.g);**
- **"Machinery" (1.A.2.h);**
- **"Mining (excluding fuels) and Quarrying" (1.A.2.i);**
- **"Wood and Wood Products" (1.A.2.j);**
- **"Construction" (1.A.2.k);**
- **"Textile and Leather" (1.A.2.l);**
- **"Non-specified Industry" (1.A.2.m).**

The above disaggregation will require additional data collection efforts from countries: while fuel consumption data may easily be available from national statistics, a differentiation with respect to technology types used in the different subsectors may be more difficult.

A detailed list of default emissions factors that have been introduced ("n") or revised ("r") in the "manufacturing industries and construction" subcategory is available in Table 2.3 of the 2006 IPCC Guidelines (Volume 2, Chapter 2 "Stationary Combustion").

**Box 1.5** – *Implications of $CH_4$ and $N_2O$ emissions from combustion processes with contact*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Implications of $CH_4$ and $N_2O$ emissions from combustion processes with contact**

Some types of production are highly energy intensive and require particular technologies of combustion with contact through materials with specific characteristics to produce final products. In the case of fuel combustion, the emissions of non-$CO_2$ gases contain very small amounts of carbon compared to the $CO_2$ estimate and, at Tier 1, it is more accurate to base the $CO_2$ estimate on the total carbon in the fuel. This is because the total carbon in the fuel depends on the fuel alone, while the emissions of the non-$CO_2$ gases depend on many factors such as technologies, maintenance etc. At higher tiers, the amount of carbon in non-$CO_2$ gases can be accounted for. Since $CO_2$ emissions are independent of combustion technology whilst $CH_4$ and $N_2O$ emissions are strongly dependent on the technology, it is necessary to investigate the production process and abatement systems to have specific indications on the emission factors of non-$CO_2$ greenhouse gases. This aspect can be significant in sector as integrated iron and steel production, non-ferrous metal, clinker and lime productions, but also in the glass or brick and tiles industries.

### *1.1.4 Transport (1.A.3)*

The Transport category is mainly concerned by methodological approaches for estimating emissions from mobile combustion, which in the 2006 IPCC Guidelines mostly correspond to the ones in the previous guidelines, with some improvements: the distinction between subcategories and their order is now clearer and more coherent; relevant decision trees have been introduced, including by re-arranging some of those included in the IPCC Good Practice Guidance; further guidance is available for the bottom-up estimation of $CH_4$ and $N_2O$ emissions and for the consideration of biofuels; and experiences with road and non-road emission models are presented. For navigation and aviation, the criteria for defining international and domestic transport were simplified: instead of evaluating whole journeys including stopovers, individual segments/legs of the journey are considered separately.
Moreover, a Tier 3 methodology is proposed for estimating off-road emissions by considering "annual hours of use and equipment-specific parameters, such as rated power, load factor, and emission factors based on power usage". This may require additional effort for collecting the corresponding data.
Specific changes occurred for Civil aviation, Road transport, Railways and Water-borne navigation subcategories are described below.

***Civil aviation (1.A.3.a)***

The methodologies for estimating emissions from aviation were generally refined and more detailed description is available in comparison to the previous guidelines, with the provision of three tier approaches. In Tier 2, the new guidelines only consider "individual aircraft types", contrarily to the previous arrangements which differentiated between aggregate aircraft movements and individual aircraft movements. A Tier 3 approach was also introduced as a new element based on flight movement data, divided into two approaches: one based on origin and destination (OD) relations (Tier 3a); and one requiring full flight trajectory information (Tier 3b). Such changes will require additional effort for data collection, and emissions may also change significantly.
Moreover, the 2006 IPCC Guidelines provide, in addition to those for $CO_2$, emission factors for $CH_4$, $N_2O$ and $NO_x$ related to uncontrolled combustion, with their uncertainty ranges; and an updated and extended list of emission factors for landing and take-off cycles (LTO) of $CO_2$, $CH_4$, $N_2O$, $NO_x$, CO, NMVOC and $SO_2$, as well as those of $NO_x$ for various aircraft types at cruise levels (Tables 3.6.9 and 3.6.10).
Regarding the estimation of cruising emissions, it is indicated that other gases (e.g. $N_2O$ and $CH_4$) cannot be included in the calculation due to limits in the current scientific understanding, while in the previous guidelines emission factors for $CH_4$ and $N_2O$ were available (although no methane emissions were assumed during cruising). For Tier 2, in the new guidelines it is indicated that only $NO_x$ emissions can be computed directly for cruise calculations based on specific emission factors, while $N_2O$ can be computed indirectly from $NO_x$ emissions.

***Road transportation (1.A.3.b)***

In the 2006 IPCC Guidelines, a new subcategory **"Urea-based catalysts" (1.A.3.b.vi)** has been introduced under Road transportation, along with a methodology for estimating non-combustive $CO_2$ emissions from urea-based catalytic converters, by multiplying the amount of urea-based additive consumed with the mass fraction of urea in the additive; this requires the collection of corresponding data. Potential double counting of emissions with the IPPU sector should be avoided.

**Box 1.6** – *Urea-based catalysts*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Urea-based catalysts**

The estimation of road transport $CO_2$ emissions from urea-based catalysts can be directly implemented by the model used (e.g. "Copert version 5.4.36", EMISIA SA, 2020, used in Italy).
The consumption of urea should be assumed based on the vehicle model and its fuel type. With regard to the purity (the mass fraction of urea in the urea-based additive), a default value of 32.5% is indicated by the 2006 IPCC Guidelines.

The updated and extended list of $CO_2$ emission factors introduced for the whole energy sector, with the assumption of full oxidation, also concerns default factors for road transport. Lists of fuel-based $CH_4$ and $N_2O$ emission factors have also been introduced for emissions from road and off-road transport, including their ranges. In addition, technology-specific $CH_4$ and $N_2O$ emission factors are provided.

**Box 1.7** – *Emission factors for new technologies*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Emission factors for new technologies**

For emission factors of technologies that were not available in the 2006 IPCC Guidelines (such as new generation cars), it is suggested to check available updates to internationally recognized models, such as EEA Copert, US EPA's MOtor Vehicle Emission Simulator (MOVES).

The 2006 IPCC Guidelines also feature the inclusion of cold start emissions in the Tier 3 methodology for estimating $CH_4$ and $N_2O$ emissions from mobile combustion. Cold start emissions correspond to fixed values depending on fuel type, vehicle type, emission control technology and operating conditions. This requires the collection of data needed as well as a recalculation of emissions for those countries already using a Tier 3 approach.

Furthermore, an approach for deriving country-specific $CH_4$ emission factors from information on total hydrocarbons (THC) has been introduced: THC may be obtained from laboratory measurements and $CH_4$ emission factors may then derived by multiplying a ratio of $CH_4$ to THC with the measured THC value.

Finally, detailed information on the consideration of biofuels is now included in the 2006 IPCC Guidelines.

**Box 1.8** – *Assessment of the biofuel origin*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Assessment of the biofuel origin**

The biofuel origin should be assessed in order to evaluate the potential $CO_2$ emissions from fossil fuel content of biofuel. According to the 2006 IPCC Guidelines, "it is important to assess the biofuel origin so as to identify and separate fossil from biogenic feedstocks".
In order to calculate the biodiesel emissions from the fossil component of the fuel, it could be assumed that "the fossil part of the FAME ranges from 5.3 to 5.5%"[5].
Furthermore, the calculation method could be implemented in the model used, for instance in EEA Copert model, biodiesel emissions from the fossil component of the fuel are calculated by the tool "fossil fuel fraction in biodiesel", on the basis of the following input data: share of fame in biodiesel (it is assumed a default percentage equal to 80%); g fossil $CO_2$/g FAME (it is assumed a default equal to 0.15); g bio $CO_2$/g FAME (2.68 is the default value), FAME Energy Content (it is assumed 37.1 MJ/kg).
Then, $CO_2$ emission values relating the fossil fraction of biodiesel could be reported under the CRF "Other Fossil Fuel" categories tables.

[5] IPCC Working Group I "Note on fossil carbon content in biofuels", prepared by Ioannis Sempos, 10 October 2018

***Railways (1.A.3.c)***
In the 2006 IPCC Guidelines, a more detailed description of the methodological approaches for railways was included, including through the introduction of decision trees.
Default fuel-based $CH_4$ and $N_2O$ emission factors for rail transport were added, including upper and lower ranges. Pollutant weighting factors are also provided allowing for a differentiation of $CH_4$ and $N_2O$ emission factors according to different uncontrolled engines. A factor for accounting deterioration of $CH_4$ emission with increasing vehicle age is also provided.
Moreover, a Tier 3 methodology for estimating $CH_4$ and $N_2O$ emissions from railways was included, taking into account annual hours of use, average rated power and typical load factors of locomotives.

Furthermore, an approach for estimating yard locomotive fuel consumption is provided. The inventory fuel consumption is then calculated by multiplying the number of yard locomotives with the average fuel consumption per locomotive and day and the average number of operating days per locomotive in the year. This may require additional effort from countries to collect the corresponding data.

***Water-borne navigation (1.A.3.d)***
For water-borne navigation, default fuel-based $CH_4$ and $N_2O$ emission factors, including uncertainty ranges, were introduced along with decision trees and more detailed methodological guidance, which altogether may require further data collection efforts and recalculations.
Moreover, tables including information on average fuel consumption per day as well as on splitting the fuel consumption between the main engine and auxiliary engines in vessels were included.

### *1.1.5 Other sectors (1.A.4)*
In **"Other sectors" (1.A.4)**, a number of default emission factors have been introduced ("n") or revised ("r"). A detailed list of changes is available in the 2006 IPCC Guidelines (Volume 2, Chapter 2 "Stationary Combustion") at a subcategory level, for "commercial and institutional" (Table 2.4) and for "residential" and "Agriculture/Forestry/Fishing/Fish Farms" (combined into Table 2.5). While most default emission factors present the same values across different subcategories, it should be emphasized that this is not always the case: in fact, some default emission factors for the same fuel and GHG vary due to the different specific technologies.

Moreover, subcategory "Agriculture/Forestry/Fishing/Fish Farms" (1.A.4.c) was further disaggregated into three more subcategories:
- "Stationary" (1.A.4.c.i);
- "Off-road Vehicles and Other Machinery" (1.A.4.c.ii);
- "Fishing (mobile combustion)" (1.A.4.c.iii).

**Box 1.9** – *Public electricity and heat production*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Public electricity and heat production**

Emissions from landfill gas recovered and used for heating and power in commercial facilities may be reported under category 1.A.4.a, biomass. However, in cases when the share of waste used to produce electricity is significantly increasing over time, countries may consider to revise the allocation of emissions from incineration with energy recovery under category 1.A.1.a.

### *1.1.6 Non-specified (1.A.5)*
Under **"Non-specified" (1.A.5)**, an additional category has been added to the 2006 IPCC Guidelines for GHG emissions from **Multilateral operations (1.A.5.c)**.
Moreover, subcategory "Mobile" (1.A.5.b) was further disaggregated into three additional subcategories:
- "Mobile" – Aviation component (1.A.5.b.i);
- "Mobile" – Water-borne component (1.A.5.b.ii);
- "Mobile" – Other (1.A.5.b.iii).

General methodological considerations and changes for stationary and mobile sources that were already introduced in previous subcategories within Fuel Combustion are also applicable to this subcategory.

### *1.1.7 Tabular summary of changes for Fuel Combustion*

**Table 1.1** – *Fuel Combustion: tabular summary of changes from the revised 1996 IPCC Guidelines to the 2006 IPCC Guidelines (highlighted in blue are disaggregated categories/subcategories, in red are new categories/subcategories).*

| 1996 IPCC Guidelines | 2006 IPCC Guidelines |
|---|---|
| | |
| **1.A Fuel Combustion Activities (Sectoral Approach)** | **1.A Fuel Combustion Activities** |
| **1.A.1 Energy Industries** | **1.A.1 Energy Industries** |
| 1.A.1.a Public Electricity and Heat Production | 1.A.1.a Main Activity Electricity and Heat Production |
| | 1.A.1.a.i Electricity Generation |
| | 1.A.1.a.ii Combined Heat and Power Generation (CHP) |
| | 1.A.1.a.iii Heat Plants |
| 1.A.1. b Petroleum Refining | 1.A.1. b Petroleum Refining |
| 1.A.1. c Manufacture of Solid Fuels and Other Energy Industries | 1.A.1. c Manufacture of Solid Fuels and Other Energy Industries |
| | 1.A.1.c.i Manufacture of Solid Fuels |
| | 1.A.1.c.ii Other Energy Industries |
| **1.A.2 Manufacturing Industries and Construction** | **1.A.2 Manufacturing Industries and Construction** |
| 1.A.2. a Iron and Steel | 1.A.2. a Iron and Steel |
| 1.A.2. b Non-Ferrous Metals | 1.A.2. b Non-Ferrous Metals |
| 1.A.2. c Chemicals | 1.A.2. c Chemicals |
| 1.A.2. d Pulp, Paper and Print | 1.A.2. d Pulp, Paper and Print |
| 1.A.2. e Food Processing, Beverages and Tobacco | 1.A.2. e Food Processing, Beverages and Tobacco |
| 1.A.2. f Other | 1.A.2. f Non-Metallic Minerals |
| | 1.A.2. g Transport Equipment |
| | 1.A.2. h Machinery |
| | 1.A.2. i Mining (excluding fuels) and Quarrying |
| | 1.A.2. j Wood and Wood Products |
| | 1.A.2. k Construction |
| | 1.A.2. l Textile and Leather |
| | 1.A.2. m Non-specified Industry |
| **1.A.3 Transport** | **1.A.3 Transport** |
| 1.A.3. a Civil Aviation | 1.A.3. a Civil Aviation |
| 1.A.3.a.i International Aviation (International Bunkers) | 1.A.3.a.i International Aviation (International Bunkers) |
| 1.A.3.a.ii Domestic Aviation | 1.A.3.a.ii Domestic Aviation |
| 1.A.3. b Road Transportation | 1.A.3. b Road Transportation |
| 1.A.3.b.i Cars | 1.A.3.b.i Cars |
| Passenger Cars with 3-way Catalysts | 1.A.3.b.i.1 Passenger Cars with 3-way Catalysts |
| Passenger Cars without 3-way Catalysts | 1.A.3.b.i.2 Passenger Cars without 3-way Catalysts |
| 1.A.3.b.ii Light-duty Trucks | 1.A.3.b.ii Light-duty Trucks |
| Light-duty Trucks with 3-way Catalysts | 1.A.3.b.ii.1 Light-duty Trucks with 3-way Catalysts |
| Light-duty Trucks without 3-way Catalysts | 1.A.3.b.ii.2 Light-duty Trucks without 3-way Catalysts |
| 1.A.3.b.iii Heavy-duty Trucks and Buses | 1.A.3.b.iii Heavy-duty Trucks and Buses |
| 1.A.3.b.iv Motorcycles | 1.A.3.b.iv Motorcycles |
| 1.A.3.b.v Evaporative Emissions from Vehicles | 1.A.3.b.v Evaporative Emissions from Vehicles |
| | 1.A.3.b.vi Urea-based Catalysts |
| 1.A.3. c Railways | 1.A.3. c Railways |

| 1996 IPCC Guidelines | 2006 IPCC Guidelines |
|---|---|
| 1.A.3. d Navigation | 1.A.3. d Water-borne Navigation |
| 1.A.3.d.i International Marine Navigation (International Bunkers) | 1.A.3.d.i International Water-borne Navigation (International Bunkers) |
| 1.A.3.d.ii National Navigation | 1.A.3.d.ii Domestic Water-borne Navigation |
| 1.A.3. e Other Transportation | 1.A.3. e Other Transportation |
| 1.A.3.e.i Pipeline Transport | 1.A.3.e.i Pipeline Transport |
| 1.A.3.e.ii Off-road | 1.A.3.e.ii Off-road |
| **1.A.4 Other Sectors** | **1.A.4 Other Sectors** |
| 1.A.4. a Commercial/Institutional | 1.A.4. a Commercial/Institutional |
| 1.A.4. b Residential | 1.A.4. b Residential |
| 1.A.4. c Agriculture/Forestry/Fisheries | 1.A.4. c Agriculture/Forestry/Fishing/Fish Farms |
| | 1.A.4.c.i Stationary |
| | 1.A.4.c.ii Off-road Vehicles and Other Machinery |
| | 1.A.4.c.iii Fishing (mobile combustion) |
| **1.A.5 Other** | **1.A.5 Non-Specified** |
| 1.A.5. a Stationary | 1.A.5. a Stationary |
| 1.A.5. b Mobile | 1.A.5. b Mobile |
| | 1.A.5.b.i Mobile (aviation component) |
| | 1.A.5.b.ii Mobile (water-borne component) |
| | 1.A.5.b.iii Mobile (other) |
| | 1.A.5. c Multilateral Operations |

### *1.1.8 2006 IPCC categories in the CRTs (Fuel Combustion)*

**Table 1.2** – *Fuel Combustion: Tabular summary of correspondence between categories and subcategories in the 2006 IPCC Guidelines and the reporting structure of UNFCCC's CRTs*

| 2006 IPCC Guidelines | CRTs (UNFCCC reporting) |
|---|---|
| | |
| **1.A Fuel Combustion Activities** | **1.A Fuel Combustion** |
| **1.A.1 Energy Industries** | **1.A.1 Energy Industries** |
| 1.A.1.a Main Activity Electricity and Heat Production | 1.A.1. a Public Electricity and Heat Production |
| 1.A.1.a.i Electricity Generation | *Child nodes can be added for further disaggregation* |
| 1.A.1.a.ii Combined Heat and Power Generation (CHP) | |
| 1.A.1.a.iii Heat Plants | |
| 1.A.1. b Petroleum Refining | 1.A.1. b Petroleum Refining |
| 1.A.1. c Manufacture of Solid Fuels and Other Energy Industries | 1.A.1. c Manufacture of Solid Fuels and Other Energy Industries |
| 1.A.1.c.i Manufacture of Solid Fuels | *Child nodes can be added for further disaggregation* |
| 1.A.1.c.ii Other Energy Industries | |
| **1.A.2 Manufacturing Industries and Construction** | **1.A.2 Manufacturing Industries and Construction** |
| 1.A.2. a Iron and Steel | 1.A.2. a Iron and Steel |
| 1.A.2. b Non-Ferrous Metals | 1.A.2. b Non-Ferrous Metals |
| 1.A.2. c Chemicals | 1.A.2. c Chemicals |
| 1.A.2. d Pulp, Paper and Print | 1.A.2. d Pulp, Paper and Print |
| 1.A.2. e Food Processing, Beverages and Tobacco | 1.A.2. e Food Processing, Beverages and Tobacco |
| 1.A.2. f Non-Metallic Minerals | 1.A.2. f Non-Metallic Minerals |
| 1.A.2. g Transport Equipment | 1.A.2. g Other *(child nodes can be added)* |
| 1.A.2. h Machinery | |

| 2006 IPCC Guidelines | CRTs (UNFCCC reporting) |
|---|---|
| 1.A.2. i Mining (excluding fuels) and Quarrying | |
| 1.A.2. j Wood and Wood Products | |
| 1.A.2. k Construction | |
| 1.A.2. l Textile and Leather | |
| 1.A.2. m Non-specified Industry | |
| **1.A.3 Transport** | **1.A.3 Transport** |
| 1.A.3. a Civil Aviation | |
| 1.A.3.a.i International Aviation (International Bunkers) | 1.D Memo item - International Bunkers (Aviation) |
| 1.A.3.a.ii Domestic Aviation | 1.A.3. a Domestic Aviation |
| 1.A.3. b Road Transportation | 1.A.3. b Road Transportation |
| 1.A.3.b.i Cars | 1.A.3.b.i Cars |
| 1.A.3.b.i.1 Passenger Cars with 3-way Catalysts | *Child nodes can be added for further disaggregation* |
| 1.A.3.b.i.2 Passenger Cars without 3-way Catalysts | |
| 1.A.3.b.ii Light-duty Trucks | 1.A.3.b.ii Light-duty Trucks |
| 1.A.3.b.ii.1 Light-duty Trucks with 3-way Catalysts | *Child nodes can be added for further disaggregation* |
| 1.A.3.b.ii.2 Light-duty Trucks without 3-way Catalysts | |
| 1.A.3.b.iii Heavy-duty Trucks and Buses | 1.A.3.b.iii Heavy-duty Trucks and Buses |
| 1.A.3.b.iv Motorcycles | 1.A.3.b.iv Motorcycles |
| 1.A.3.b.v Evaporative Emissions from Vehicles | Included in 1.A.3.b.i-iv |
| 1.A.3.b.vi Urea-based Catalysts | 2.D.3 Other (IPPU sector) |
| 1.A.3. c Railways | 1.A.3. c Railways |
| 1.A.3. d Water-borne Navigation | |
| 1.A.3.d.i International Water-borne Navigation (International Bunkers) | 1.D Memo item - International Bunkers (Navigation) |
| 1.A.3.d.ii Domestic Water-borne Navigation | 1.A.3. d Domestic navigation |
| 1.A.3. e Other Transportation | 1.A.3. e Other Transportation |
| 1.A.3.e.i Pipeline Transport | 1.A.3.e.i Pipeline Transport |
| 1.A.3.e.ii Off-road | 1.A.3.e.ii Other *(child nodes can be added)* |
| **1.A.4 Other Sectors** | **1.A.4 Other Sectors** |
| 1.A.4. a Commercial/Institutional | 1.A.4. a Commercial/Institutional |
| 1.A.4. b Residential | 1.A.4. b Residential |
| | 1.A.4.b.i Stationary combustion |
| | 1.A.4.b.ii Off-road Vehicles and Other Machinery |
| | 1.A.4.b.iii Other *(child nodes can be added)* |
| 1.A.4. c Agriculture/Forestry/Fishing/Fish Farms | 1.A.4. c Agriculture/Forestry/Fishing |
| 1.A.4.c.i Stationary | 1.A.4.c.i Stationary |
| 1.A.4.c.ii Off-road Vehicles and Other Machinery | 1.A.4.c.ii Off-road Vehicles and Other Machinery |
| 1.A.4.c.iii Fishing (mobile combustion) | 1.A.4.c.iii Fishing |
| **1.A.5 Non-Specified** | **1.A.5 Other (not specified elsewhere)** |
| 1.A.5. a Stationary | 1.A.5. a Stationary *(child nodes can be added)* |
| 1.A.5. b Mobile | 1.A.5. b Mobile *(child nodes can be added)* |
| 1.A.5.b.i Mobile (aviation component) | *Child nodes can be added for further disaggregation* |
| 1.A.5.b.ii Mobile (water-borne component) | |
| 1.A.5.b.iii Mobile (other) | |
| 1.A.5. c Multilateral Operations | 1.D Memo item - Multilateral Operations |

**Box 1.10** – *Reporting tips for fuel combustion*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

## Reporting tips for fuel combustion

The revised tables in the 2006 IPCC Guidelines allow for a more detailed reporting of emissions using drop-down lists.

For "CRF 1.A.1", emissions from combined heat and power (CHP) plants may now be reported separately (optional). Reporting of emissions from micro-CHP plants constitutes a challenge due to the reporting in the energy balance of the fuel use (natural gas) in the public sector and of the corresponding heat in the residential sector. This would require reporting of "IE".

For "CRF 1.A.2", emissions may be reported with a more detailed disaggregation under "Other" by using a drop-down list. A more detailed split of emissions may entail problems of confidentiality of data since few companies may be included in each sub-category.

The further split in "CRF 1.A.3.b" according to different vehicle types is mandatory and is generally considered to be straightforward for many countries; the split is already reported under UNECE. However, some countries do not include this split in their energy balance.

Elements to be reported under "CRF 1.A.3.b.v" (Other) are not specifically defined.

## 1.2 Fugitive emissions (1.B)

### *1.2.1 Overarching changes*

The "Fugitive emissions" category (1.B) was improved in the 2006 IPCC Guidelines featuring new subcategories and a revised, clearer structure with the re-arrangement of some subcategories which may require countries to reallocate emissions. A new reporting element for "Other emissions from Energy Production" (1.B.3) was introduced in the new guidelines, comprising emissions from geothermal energy production. Especially for countries using geothermal energy, this may require additional methodological and data collection effort.

Several decision trees to guide countries in the identification of the appropriate tier approach were introduced in the new guidelines, along with updated and extended lists of emission factors to estimate fugitive emissions from both solid fuel and oil and natural gas operations.

**Box 1.11** – *Fugitive emissions in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Fugitive emissions in the 2019 Refinement**

The 2019 Refinement undertook a substantial revision of the 2006 Guidelines with respect to fugitive emissions, offering further useful details and guidance that help improving domestic reporting on fugitive emissions, including on:

- Fugitive emissions from mining, processing, storage and transportation of coal: new guidance included on fugitive $CO_2$ emissions from underground and surface mines including $CO_2$ from methane utilization or flaring from underground coal mines. Year-specific default input values for fugitive $CH_4$ emissions from abandoned underground mines were extended from 2016 to the 2017-2050 period.
- Fugitive emissions from oil and natural gas systems: emission factors were updated to reflect the range of technologies and practices in use, including for unconventional oil and gas exploration. Additional detail on the appropriate selection of factors considering technologies and practices in place is provided, as well as methods and emission factors for abandoned wells. Moreover, specific annexes were included providing inventory compilers with further guidance.
- Fugitive emissions from fuel transformation, for which a new section was added, including methods for fugitive emissions from charcoal production, biochar production, coke production (including flaring), gasification transformation processes (coal to liquids, and gas to liquids).

It is therefore highly recommended to take advantage of these refinements, although their application is only voluntary at the present date.

### *1.2.2 Solid fuel (1.B.1)*

#### *Coal mining and handling (1.B.1.a)*

Two additional subcategories under **"Underground mines" (1.B.1.a.i)** were included in the 2006 IPCC Guidelines to estimate emissions from:

- **"Abandoned underground mines"** (1.B.1.a.i.3), as coal mines that were significant methane emitters while in operation may continue emitting methane after closure. For these $CH_4$ emissions, a methodological approach is introduced requiring some additional data collection efforts. Methane emissions are computed as the emissions from abandoned mines minus methane emissions recovered. Methane emissions are estimated by multiplying the number of abandoned coal mines which remain unflooded with a fraction of gassy coal mines and an emission factor (cubic metres per year). Three approaches are proposed along a specific decision tree (Figure 4.1.3): the Tier 1 approach, which requires countries to choose from a global average range of emission factors and to use country specific activity data to calculate emissions. Specifically, it is based on the total number of coal mines abandoned, adjusted for the fraction considered gassy, and their approximate time interval of abandonment. This approach ultimately allows to determine decreasing methane emissions from abandoned coal mines over time. The Tier 2 approach, similar to Tier 1 but incorporating coal-type-specific information and narrower time intervals. Default values for active mine emissions prior to abandonment, as well as coefficients for determining the decline curve needed in the equation, are provided in the guidelines. The Tier 3 approach, which is more flexible and can be based on directly measured emissions or on models. In countries with good coal statistics, the collection of this data should not be too difficult. Since this is a new source category, overall emissions reported will probably increase.

- **"Flaring of drained methane or conversion of methane to $CO_2$"** (1.B.1.a.i.4): $CO_2$ and $CH_4$ emissions from drained methane flared or catalytically oxidised were introduced as a new element in the 2006 IPCC Guidelines, with respective equations for estimation. These are estimated based on the volume of methane flared, which needs to be collected, and the combustion efficiency of the flare be estimated. Three approaches are available: under Tier 1, emission factors are used to produce aggregate emissions estimates, although, if methane is being drained, it is expected there would be better data enabling the use of Tier 2 or Tier 3. Under both Tier 1 and 2, if methane is drained or vented to the atmosphere rather than used, it should not be recounted. Under Tier 3, methane recovered from degasification systems and vented to the atmosphere prior to mining should be added to the amount of methane released through ventilation systems to ensure completeness in the estimation. Specific indications for when recovered methane is used are provided. However, this should not pose major problems compared to previous arrangements, since monitoring data may be available due to national regulations. The consideration of this source may increase overall emissions of the inventory. It is also specified that "**methane emissions associated with coal seam degasification**" need to be reported in the inventory year in which the emissions and recovery operations occur, while in the previous guidelines it was accounted for in the year in which the coal seam was mined. This change requires a recalculation for the whole time series.

***Uncontrolled combustion and burning coal dumps (1.B.1.b)***

Emissions from **"Uncontrolled combustion and burning of coal dumps"** (1.B.1.b), due to coal exploration activities, were included as a new subcategory as they may be significant for an individual coal mine. However, overall significance at the country level is not clear and no estimation methods are provided in the 2006 IPCC Guidelines for low temperature oxidation and uncontrolled combustion. It is suggested that countries that have data on amounts of coal burned, should estimate CO2 emissions on the basis of the carbon content of coal (a rough estimation method was available in the 1996 IPCC Guidelines).

### *1.2.3 Oil and natural gas (1.B.2)*

The reporting structure of fugitive emissions from **"Oil and natural gas" (1.B.2)** activities was changed in the 2006 IPCC Guidelines. **Venting and flaring** which was included in a single, separate category in the 1996 IPCC Guidelines are now incorporated as independent subcategories of the Oil (1.B.2.a.i, 1.B.2.a.ii) and Natural gas (1.B.2.b.i, 1.B.2.b.ii) subcategories, respectively.

**Box 1.12** – *Natural gas distributed through the network or transported to site*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Natural gas distributed through the network or transported to site**

In some countries, the quantity of natural gas being distributed could be significantly lower than the quantity of natural gas transmitted in the whole time series. This situation may occur when a significant proportion of natural gas does not go through the distribution network but is instead directly transported to industrial sites, including for energy production.

Moreover, implied emission factors (e.g. $CH_4$ IEF of gas distribution) may vary significantly compared to default EF in the 2006 IPCC Guidelines. In this sense, it may be the case that EFs are generated by combining measured data obtained directly from the main gas operators with calibrated estimates from smaller operators. Explanations of any gap in activity data between gas transmission and distribution, as well as differences between implied and default emission factors from the 2006 IPCC Guidelines should be included when reporting.

In the 2006 IPCC Guidelines, an extensive discussion of the methodological approaches available (Tiers 1 to 3) is included and complemented with the provision of specific decision trees for natural gas systems, crude oil production and crude oil transport, refining and upgrading (Figures from 4.2.1 to 4.2.3). In general, the approach for the oil and gas sector is similar to the one in the previous guidelines for Tier 1, while the Tier 2 approach for estimating emissions due to venting and flaring was re-structured. A "conservation efficiency" (CE) variable was introduced in replacement of the previous approach for determining an emission factor "K", as well as an equation for the estimation of $N_2O$ emissions from flaring. Further guidance on obtaining activity data for the Tier 1 approach in oil and gas operations is also provided.

Moreover, an updated and extended list of Tier 1 default emission factors for $CH_4$, $CO_2$, NMVOC and $N_2O$ emissions from oil and gas operations for developed countries (Table 4.2.4) and for developing countries and countries with economies in transition (Table 4.2.5) were included, marking a significant improvement compared to the previous lists. This could potentially require countries to perform recalculations to ensure consistency of time series. On the contrary, emission factors for Tier 2 and Tier 3 assessments were not included due to their large amount and rapid updating, with the indication to refer to the EFDB.

**Box 1.13** – *Emission factors for oil and gas exploration activities*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Emission factors for oil and gas exploration activities**

In the 2006 IPCC Guidelines, the tier 1 methodology and default emission factors for oil and gas exploration activities are based on the volume of oil production, rather than on the number of wells (as it used to be in the IPCC Good Practice Guidance). As a result, it is worth noting that the 2006 IPCC Guidelines do not provide countries with relevant emission factors in the scenario when the only activity data available are the number of wells (with no data available on their production), potentially introducing a number of issues.

Indeed, if overall oil production were used as a proxy in estimating emissions from oil and gas exploration, there could be overestimations. For example, if production were stable over the years, yet drilling and testing occurred in some years and not in others, using the 2006 IPCC Guidelines would result in stable emissions, even for years with no drilling or exploration activity. Moreover, the methodology in the 2006 IPCC Guidelines does not reflect the situation when countries' oil production is onshore, while exploration is done offshore.

For these reasons, it is highly suggested that countries carefully evaluate whether default emission factors for oil and gas exploration activities in the 2006 IPCC Guidelines adequately reflect their national circumstances. If this is not the case, for such activities it is suggested to refer to EFs from the IPCC Good Practice Guidance and to provide specific explanations in the National Inventory Report on why using the IPCC Good Practice Guidance rather than the more recent 2006 IPCC Guidelines better reflects national circumstances.

### *1.2.4 Tabular summary of changes for Fugitive Emissions*

**Table 1.3** – *Fugitive Emissions: tabular summary of changes from the revised 1996 IPCC Guidelines to the 2006 IPCC Guidelines (highlighted in red are new categories/subcategories, highlighted in green consolidated ones).*

| **1996 IPCC Guidelines** | **2006 IPCC Guidelines** |
|---|---|
| | |
| **1.B Fugitive Emissions from Fuels** | **1.B Fugitive Emissions from Fuels** |
| **1.B.1 Solid Fuel** | **1.B.1 Solid Fuel** |
| 1.B.1.a Coal Mining and Handling | 1.B.1.a Coal Mining and Handling |
| 1.B.1.a.i Underground Mines | 1.B.1.a.i Underground Mines |
| 1.B.1.a.i.1 Mining Activities | 1.B.1.a.i.1 Mining |
| 1.B.1.a.i.2 Post-mining Activities | 1.B.1.a.i.2 Post-mining Seam Gas Emissions |
| | 1.B.1.a.i.3 Abandoned Underground Mines |
| | 1.B.1.a.i.4 Flaring of Drained Methane or Conversion of Methane to $CO_2$ |
| 1.B.1.a.ii Surface Mines | 1.B.1.a.ii Surface Mines |
| 1.B.1.a.ii.1 Mining Activities | 1.B.1.a.ii.1 Mining |
| 1.B.1.a.ii.2 Post-mining Activities | 1.B.1.a.ii.2 Post-mining Seam Gas Emissions |
| | 1.B.1.b Uncontrolled Combustion, and Burning Coal Dumps |
| 1.B.1.b Solid Fuel Transformation | 1.B.1.c Solid Fuel Transformation |
| 1.B.1.c Other | |
| **1.B.2 Oil and Natural Gas** | **1.B.2 Oil and Natural Gas** |
| 1.B.2.a Oil | 1.B.2.a Oil |
| | 1.B.2.a.i Venting |
| | 1.B.2.a.ii Flaring |
| | 1.B.2.a.iii All Other |
| 1.B.2.a.i Exploration | 1.B.2.a.iii.1 Exploration |

| 1996 IPCC Guidelines | 2006 IPCC Guidelines |
|---|---|
| 1.B.2.a.ii Production and Upgrading | 1.B.2.a.iii.2 Production and Upgrading |
| 1.B.2.a.iii Transport | 1.B.2.a.iii.3 Transport |
| 1.B.2.a.iv Refining / Storage | 1.B.2.a.iii.4 Refining |
| 1.B.2.a.v Distribution of Oil Products | 1.B.2.a.iii.5 Distribution of Oil Products |
| 1.B.2.a.vi Others | 1.B.2.a.iii.6 Others |
| 1.B.2.b Natural Gas | 1.B.2.b Natural Gas |
| | 1.B.2.b.i Venting |
| | 1.B.2.b.ii Flaring |
| | 1.B.2.b.iii All Other |
| 1.B.2.b.i Exploration | 1.B.2.b.iii.1 Exploration |
| 1.B.2.b.ii Production / Processing | 1.B.2.b.iii.2 Production |
| | 1.B.2.b.iii.3 Processing |
| 1.B.2.b.iii Transmission and Storage | 1.B.2.b.iii.4 Transmission and Storage |
| 1.B.2.b.iv Distribution | 1.B.2.b.iii.5 Distribution |
| 1.B.2.b.v Other Leakage | 1.B.2.b.iii.6 Others |
| at industrial plants and power stations | |
| in residential and commercial sectors | |
| 1.B.2.c Venting and Flaring | |
| Venting | |
| i. Oil | |
| ii. Gas | |
| iii. Combined | |
| Flaring | |
| i. Oil | |
| ii. Gas | |
| iii. Combined | |
| 1.B.2.d Other | **1.B.3 Other Emissions from Energy Production** |

### *1.2.5 2006 IPCC categories in the CRTs (Fugitive Emissions)*

**Table 1.4** – *Fugitive Emissions: tabular summary of correspondence between categories and subcategories in the 2006 IPCC Guidelines and the reporting structure of UNFCCC's CRTs*

| 2006 IPCC Guidelines | CRTs (UNFCCC reporting) |
|---|---|
| | |
| **1.B Fugitive Emissions from Fuels** | **1.B Fugitive Emissions from Fuels** |
| **1.B.1 Solid Fuel** | **1.B.1 Solid Fuel** |
| 1.B.1.a Coal Mining and Handling | 1.B.1.a Coal Mining and Handling |
| 1.B.1.a.i Underground Mines | 1.B.1.a.i Underground Mines |
| 1.B.1.a.i.1 Mining | 1.B.1.a.i.1. Mining activities |
| 1.B.1.a.i.2 Post-mining Seam Gas Emissions | 1.B.1.a.i.2. Post-mining activities |
| 1.B.1.a.i.3 Abandoned Underground Mines | 1.B.1.a.i.3. Abandoned underground mines |
| 1.B.1.a.i.4 Flaring of Drained Methane or Conversion of Methane to $CO_2$ | 1.B.1.a.i.4. Flaring of drained methane or conversion of methane to $CO_2$ |
| | 1.B.1.a.i.5. Other *(child nodes can be added)* |
| 1.B.1.a.ii Surface Mines | 1.B.1.a.ii Surface Mines |
| 1.B.1.a.ii.1 Mining | 1.B.1.a.ii.1. Mining activities |
| 1.B.1.a.ii.2 Post-mining Seam Gas Emissions | 1.B.1.a.ii.2. Post-mining activities |
| | 1.B.1.a.ii.3. Other *(child nodes can be added)* |
| 1.B.1.b Uncontrolled Combustion, and Burning Coal Dumps | |

| 2006 IPCC Guidelines | CRTs (UNFCCC reporting) |
|---|---|
| 1.B.1.c Solid Fuel Transformation | 1.B.1.b Fuel Transformation *(child nodes can be added)* |
| | 1.B.1.c Other *(child nodes can be added)* |
| **1.B.2 Oil and Natural Gas** | **1.B.2 Oil, Natural Gas and other emissions from energy production** |
| 1.B.2.a Oil | 1.B.2.a Oil |
| 1.B.2.a.i Venting | 1.B.2.c.i.1 Venting (oil) |
| 1.B.2.a.ii Flaring | 1.B.2.c.ii.1 Flaring (oil) |
| 1.B.2.a.iii All Other | |
| 1.B.2.a.iii.1 Exploration | 1.B.2.a.i Exploration |
| 1.B.2.a.iii.2 Production and Upgrading | 1.B.2.a.ii Production and Upgrading |
| 1.B.2.a.iii.3 Transport | 1.B.2.a.iii Transport |
| 1.B.2.a.iii.4 Refining | 1.B.2.a.iv Refining /storage |
| 1.B.2.a.iii.5 Distribution of Oil Products | 1.B.2.a.v Distribution of Oil Products |
| 1.B.2.a.iii.6 Others | 1.B.2.a.vi Other *(child nodes can be added)* |
| 1.B.2.b Natural Gas | 1.B.2.b Natural Gas |
| 1.B.2.b.i Venting | 1.B.2.c.i.2 Venting (gas) |
| 1.B.2.b.ii Flaring | 1.B.2.c.ii.2 Flaring (gas) |
| 1.B.2.b.iii All Other | |
| 1.B.2.b.iii.1 Exploration | 1.B.2.b.i Exploration |
| 1.B.2.b.iii.2 Production | 1.B.2.b.ii Production and Gathering |
| 1.B.2.b.iii.3 Processing | 1.B.2.b.iii Processing |
| 1.B.2.b.iii.4 Transmission and Storage | 1.B.2.b.iv Transmission and storage |
| 1.B.2.b.iii.5 Distribution | 1.B.2.b.v Distribution |
| 1.B.2.b.iii.6 Others | 1.B.2.b.vi Other *(child nodes can be added)* |
| | 1.B.2.c.i.3 Venting Combined (oil & gas) |
| | 1.B.2.c.ii.3 Flaring Combined (oil & gas) |
| **1.B.3 Other Emissions from Energy Production** | 1.B.2.d Other *(child nodes can be added)* |

**Box 1.14** – *Reporting tips for fugitive emissions*

## SUGGESTIONS AND REMARKS FROM EXPERTS

### Reporting tips for fugitive emissions

With regard to coal mining, discussions among experts noted that a mine can only be considered as sealed (non-emitting) once it is flooded; otherwise, emissions or flaring would need to be reported. Abandoned and closed mines are considered together. Closed mines typically retain water pumping infrastructure, so that the mine may be opened again. An abandoned mine is gradually flooded without pumping. Discussions among experts also noted that the estimation of fugitive emissions is often based on throughput, which seems to lead to quite high emissions estimates.

Moreover, it should be noted that while methane drained and flared, or ventilation gas converted to $CO_2$ by an oxidation process should be included under subcategory "1.B.1.a.i.4", methane used for energy production should be included under the Energy sector among stationary combustion sources.

Finally, it is worth highlighting that while the 2006 IPCC Guidelines have a new subcategory "Other Emissions from Energy Production" (1.B.3), such change was not reflected in the structure of the CRTs: as a result, countries willing to report on such activities are suggested to do so through "Other" (1.B.2.d).

## 1.3 Carbon dioxide transport and storage (1.C)

### *1.3.1 Overarching changes*

**"Carbon Dioxide Transport and Storage" (1.C)** was introduced as a new source category in the 2006 IPCC Guidelines to reflect the growing relevance of Carbon Capture and Storage (CCS) technologies, with a brief description of the process and its chain. Emissions associated with $CO_2$ transport, injection and storage are covered under this category, while emissions (and reductions) associated with $CO_2$ capture are briefly discussed but should be reported under the IPCC sector in which capture takes place: the section indicates the location of the guidelines for compiling inventories of emissions from the $CO_2$ capture and compression systems, depending on the nature of the source:

- Stationary combustion systems (Energy, Stationary combustion - section 2.3.4), where the three main approaches for capturing $CO_2$ arising from the combustion of fossil fuels and/or biomass are presented (Figure 2.5).
- Natural gas processing plants and Hydrogen production plants (Energy, Fugitive emissions from oil and natural gas systems - section 4.2.1).
- Capture from industrial processes: cement manufacture, ammonia production, methanol manufacture, iron and steel manufacture (IPPU - sections 2.2, 3.2, 3.9 and 4.2, respectively).

The reference approach in the 2006 IPCC Guidelines includes a more detailed description of the different carbon flows that have to be excluded. In addition, non-fuel uses are now included in the IPPU sector. This may require some re-structuring of data and potentially some recalculations.
Guidance to develop a Tier 3 methodology for $CO_2$ emissions from geological storage based on monitored data from the storage sites is provided, along with experiences of $CO_2$ injection projects. A Tier 3 reporting is required on a plant level since $CO_2$ capture is still an emerging technology. $CO_2$ emissions are calculated from the estimated amount of $CO_2$ produced from the fuel consumption minus the amount of $CO_2$ captured. The capture of $CO_2$ emissions from biogenic sources is included in the inventory as "negative emissions" to avoid a distinction between any subsequent leakage of biogenic $CO_2$ and of $CO_2$ from fossil sources.
This new category is divided into three subcategories:

- **"Transport of $CO_2$" (1.C.1)**;
- **"Injection and Storage" (1.C.2)**; and
- **"Other" (1.C.3)**.

**Box 1.15 –** *$CO_2$ capture and storage activities*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**$CO_2$ capture and storage activities**

Emissions from $CO_2$ capture and storage are covered comprehensively in the new guidelines, including fugitive losses from $CO_2$ capture and transport stages (which are estimated using conventional inventory approaches) plus any losses from carbon dioxide stored underground (estimated by a combination of modelling and measurement techniques, given the amounts injected). Inventory methods reflect the estimated actual emissions in the year in which they occur. Inventory methods for geological $CO_2$ capture, transport and storage (CCS) provided are consistent with the IPCC Special Report on Carbon Dioxide Capture and Storage (2005). Amounts of $CO_2$ captured from combustion of biofuel, and subsequently injected into underground storage are included in the inventory as a negative emission. No distinction is made between any subsequent leakage of this $CO_2$ and that of $CO_2$ from fossil sources.

### *1.3.2 Transport of $CO_2$ (1.C.1)*

This subcategory is further sub-divided into:

- "Pipelines" (1.C.1.a), which are fugitive emissions from the pipeline system used to transport $CO_2$ to the injection site. This activity is discussed more broadly, including through guidance on the derivation of default emission factors for $CO_2$ pipeline transport.
- "Ships" (1.C.1.b), which are fugitive emissions from the ships used to transport $CO_2$ to the injection site; default emission factors for this activity are not available.
- "Other" (1.C.1.c), to be specified, which are those emissions from other systems used to transport $CO_2$ to the injection site and temporary storage.

Guidance is provided to estimate default emission factors for $CO_2$ pipeline transport based on emission factors for pipeline transport of natural gas. Default Tier 1 emission factors for fugitive emissions from

$CO_2$ transportation by pipeline are provided including lower, medium and high values as well as an uncertainty estimate.

### *1.3.3 Injection and Storage (1.C.2)*

This subcategory is further sub-divided into Injection (1.C.2.a), defined as "fugitive emissions from activities and equipment at the injection site" and Storage (1.C.2.b), defined as "fugitive emissions from the end containment once the $CO_2$ is placed in storage". The two activities are briefly discussed in the guidelines, including a description of emission pathways/sources.
The guidance provided in the new guidelines refers to "geological storage", but not to other storage options such as "ocean storage or conversion $CO_2$ into inert inorganic carbonates".

### *1.3.4 Other (1.C.3)*

This subcategory represents "any other" fugitive emissions from CCS which are not reported elsewhere.

### *1.3.5 Tabular summary of changes for Carbon Dioxide Transport and Storage*

**Table 1.5** – *Carbon Dioxide Transport and Storage: tabular summary of changes from the revised 1996 IPCC Guidelines to the 2006 IPCC Guidelines (the entire table is highlighted in red since the whole category is new compared to the 1996 IPCC Guidelines)*

| 1996 IPCC Guidelines | 2006 IPCC Guidelines |
|---|---|
| | |
| | **1.C Carbon Dioxide Transport and Storage** |
| | **1.C.1 Transport of CO2** |
| | 1.C.1.a Pipelines |
| | 1.C.1.b Ships |
| | 1.C.1.c Other |
| | **1.C.2 Injection and Storage** |
| | 1.C.2.a Injection |
| | 1.C.2.b Storage |
| | **1.C.3 Other** |

### *1.3.6 2006 IPCC categories in the CRTs (Carbon Dioxide Transport and Storage)*

**Table 1.6** – *Carbon Dioxide Transport and Storage: tabular summary of correspondence between categories and subcategories in the 2006 IPCC Guidelines and the reporting structure of UNFCCC's CRTs*

| 2006 IPCC Guidelines | CRTs (UNFCCC reporting) |
|---|---|
| | |
| **1.C Carbon Dioxide Transport and Storage** | **1.C $CO_2$ Transport and Storage** |
| **1.C.1 Transport of $CO_2$** | **1.C.1 Transport of $CO_2$** |
| 1.C.1.a Pipelines | 1.C.1.a Pipelines |
| 1.C.1.b Ships | 1.C.1.b Ships |
| 1.C.1.c Other | 1.C.1.c Other *(child nodes can be added)* |
| **1.C.2 Injection and Storage** | **1.C.2 Injection and Storage** |
| 1.C.2.a Injection | 1.C.2.a Injection |
| 1.C.2.b Storage | 1.C.2.b Storage |
| **1.C.3 Other** | **1.C.3 Other** *(child nodes can be added)* |

# 2 INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)

## Overview

The 2006 IPCC Guidelines introduced a significant change in its structure: the previous categories covering "Industrial Processes" and, separately, "Solvent and Other Product Use", in the 1996 IPCC Guidelines were integrated into a single sector named **"Industrial Processes and Product Use" (IPPU)**. Accordingly, several changes occurred. The IPPU sector in the new guidelines provides an extensive introductory chapter, dealing with general and cross-cutting issues, nature of non-energy uses of fossil fuels, quality control of completeness and allocation of $CO_2$ from non-energy uses, guidance on choosing between the mass-balance and emission-factor approaches, which overall represent a significant improvement since the 1996 IPCC Guidelines. Some of the main new elements and changes are illustrated below.

As anticipated in the Energy sector module, the 2006 IPCC Guidelines also provide 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**.

Moreover, emissions from non-energy uses of fuels are reported under IPPU and no longer under Energy, and a method for checking the completeness of carbon dioxide emission estimates from the non-energy uses has been introduced.

**Box 2.1** – *Allocating emissions between Energy and IPPU sectors*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Allocating emissions between Energy and IPPU sectors**

Allocating emissions from the use of fossil fuel between the Energy and 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. In the 2006 IPCC Guidelines, the following rule has been formulated to simplify reporting:
*"Combustion emissions from fuels obtained directly or indirectly from the feedstock for an IPPU process will normally be allocated to the part of the source category in which the process occurs. These source categories are normally 2.B and 2.C. However, if the derived fuels are transferred for combustion in another source category, the emissions should be reported in the appropriate part of Energy Sector source categories (normally 1.A.1 or 1.A.2)."*

Two examples are provided for illustration of this definition:
*1. If blast furnace gas is combusted entirely within the Iron and Steel industry (whether for heating blast air, site power needs or for metal finishing operations) the associated emissions are reported in the IPPU source subcategory 2.C.1. If part of the gas is delivered to a nearby brickworks for heat production or a main electricity producer then the emissions are reported in source subcategories (1.A.2.f or 1.A.1.a).*
*2. If surplus methane or hydrogen from the steam cracking of naphtha is combusted within the petrochemical site for another process then the emissions are reported as emissions in IPPU, 2B8. On the other hand, if the gases are passed to a nearby refinery for fuel use, then the associated emissions would be reported under 1A1b, Petroleum Refining.*

The 2006 IPCC Guidelines also include "**indirect $N_2O$ emissions**", i.e. emissions from deposition of nitrogen containing compounds onto soils, in the IPPU Sector. In the previous guidelines, only indirect $N_2O$ emissions from agriculture sources were included. The methodology attributes all indirect emissions of $N_2O$ to the original source of the nitrogen.

The 2006 IPCC Guidelines have been expanded to cover **new source categories and new gases**: specifically, more manufacturing sectors and product uses identified as sources of GHGs are included. These include $N_2O$ emissions from caprolactam, glyoxal and glyoxylic acid production, $CO_2$ emissions from titanium dioxide, lead, zinc and petrochemicals production, and liquid crystal display (LCD) manufacturing. Additional GHGs are also included where anthropogenic sources have been identified. These gases include nitrogen trifluoride ($NF_3$), trifluoromethyl sulphur pentafluoride ($SF_5CF_3$), halogenated ethers and other halocarbons not covered by the Montreal Protocol.

**Box 2.2** – *Overall improvements for the IPPU sector in the 2019 Refinement*

| SUGGESTIONS AND REMARKS FROM EXPERTS |
|---|
| **Overall improvements for the IPPU sector in the 2019 Refinement**<br>In the 2019 Refinement, new source categories (production of hydrogen, rare earth metals and alumina, and waterproofing of circuit boards) and new gases were included: additional hydrofluorocarbons, perfluorocarbons, and halogenated ethers (a perfluoropolyether widely used as a heat transfer fluid in electronics manufacturing); and several source categories were updated and elaborated: nitric acid, fluorochemicals, iron and steel, aluminium, and electronics, and production and use of refrigeration and air-conditioning equipment. |

The potential emissions approach used as a Tier 1 method in the 1996 IPCC Guidelines is no longer considered appropriate to estimate actual emissions of fluorinated compounds, as it does not provide estimates of true emissions, and is not compatible with higher tiers. The Tier 1 methods proposed in this volume are therefore actual emission estimation methods, although these are often based on default activity data where better data are not available. Simplified mass balance approaches have also been proposed in appropriate sectors, such as refrigeration.

**Box 2.3** – *Summary of main improvements from the 1996 to the 2006 IPCC Guidelines for the IPPU sector*

| MAIN SPECIFIC IMPROVEMENTS ACROSS THE IPPU SECTOR | |
|---|---|
| Added: | - New categories (i.e. production of lead, zinc, titanium dioxide, and liquid crystal display (LCD) manufacturing; Caprolactam, glyoxal and glyoxylic acid production; Petrochemical and carbon black production).<br>- New gases: nitrogen trifluoride ($NF_3$), trifluoromethyl Sulphur pentafluoride ($SF_5CF_3$), halogenated ethers, and sulphur Hexafluoride and per-fluorocarbons from other product use. |
| Revised: | - Merging of previous standalone sectors "Industrial Processes" and "Solvent and Other Product Use".<br>- Indirect $N_2O$ emissions sources expanded, i.e. emissions from deposition of nitrogen containing compounds onto soils (previously, only agricultural sources were included).<br>- Revision of some methodologies and emission factors. |

## 2.1 Mineral Industry (2.A)

### *2.1.1 Overarching changes*

In the 2006 IPCC Guidelines, guidance for mineral industry emissions is enhanced compared to previous ones. In particular, a number of subcategories were consolidated (i.e. glass production, other process uses of carbonates, and others) and arranged to highlight the source categories that have relatively higher contribution to global emissions, while the processes being similar. In addition to a description of Tier 1 and Tier 2 methods (with significant changes being outlined in the paragraphs below), a new input-based method (Tier 3) was introduced to estimate emissions based on quantity, type and composition of carbonate inputs to production process and integrated into each subcategory.

A specific table (Table 2.1, page 2.7) including formulae, formula weights and carbon dioxide contents of common carbonate species was added. Guidance for the choice of emission factors and activity data was provided, and decision trees for the estimation of $CO_2$ emissions from each major source category (cement production, lime production, glass production) were added, as well as tables with default uncertainty values for major source production.

**Box 2.4** – *Establishing Domestic Databases for punctual sources of emissions*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Establishing Domestic Databases for punctual sources of emissions**

With the view of having country specific/industrial facility specific information, it is suggested that countries introduce domestic databases for point sources of emission (both GHG and others). Such databases allow to gain specific information on activity data and associated $CO_2$ and $N_2O$ emissions, distinguishing between "energy" and "process" aspects to allow for a correct allocation of emissions, as well as to adopt an approach to the estimation process that appears as an hybrid between Tier 2 and Tier 3 (by building very specific emission factors, although additional information may be missing not allowing for the use of a Tier 3).

### *2.1.2 Cement production (2.A.1)*

For cement production, in addition to Tier 3 methodology as described above, some guidance was updated. In particular: for Tier 1, a cement kiln dust (CKD) correction factor (1.02) was included in the emission factor, which changes from 0.51 to 0.52 t $CO_2$ / t clinker; and for Tier 2, general more guidance was provided to develop country-specific emission factors and to account for CaO from non-carbonate sources (e.g. steel slag, fly ash), with an indication that no correction for MgO is necessary in Tier 2. No changes occurred in default emission factors or CKD.

### *2.1.3 Lime Production (2.A.2)*

For lime production, few specific changes occurred in addition to general ones outlined above. In particular, there were no changes for Tier 1 while a lime kiln dust (LKD) correction factor (LKD = 1.02) was introduced under Tier 2.

### *2.1.4 Glass Production (2.A.3)*

Glass production is a new consolidated category, such emissions were earlier included in other categories. In the 2006 IPCC Guidelines, Tier 1 methodology based on national level glass production statistics, as well as Tier 2 methodology based on different glass manufacturing processes are included, while they were not covered by the previous guidelines.

### *2.1.5 Other process uses of carbonates (2.A.4)*

This represents a new source category, consolidating/including the following subcategories which were previously reported differently: ceramics, other uses of soda ash, non-metallurgical magnesia production, other uses. Tier 1 method only considers limestone and dolomite used and default fraction limestone / dolomite; Tier 2 method only considers limestone and dolomite used, and national data on limestone and dolomite used; and Tier 3 considers all carbonate inputs. The principle to be applied is to report emissions in the industries where they occur (e.g. shift in the use of limestone, dolomite and other carbonates).

### *2.1.6 Tabular summary of changes for Mineral Industry*

**Table 2.1** – *Mineral Industry: tabular summary of changes from the revised 1996 IPCC Guidelines to the 2006 IPCC Guidelines. (highlighted in green are consolidated categories/subcategories).*

| 1996 IPCC Guidelines | 2006 IPCC Guidelines |
|---|---|
| | |
| **2.A Mineral Products** | **2.A Mineral Industry** |
| **2.A.1 Cement Production** | **2.A.1 Cement Production** |
| **2.A.2 Lime Production** | **2.A.2 Lime Production** |
| **2.A.3 Limestone and Dolomite Use** | **2.A.3 Glass Production** |
| | **2.A.4 Other Process Uses of Carbonates** |
| | 2.A.4.a Ceramics |
| **2.A.4 Soda Ash Production and Use** | 2.A.4.b Other Uses of Soda Ash |
| **2.A.3 Limestone and Dolomite Use** | 2.A.4.c Non Metallurgical Magnesium Production |
| | 2.A.4.d Other |
| **2.A.5 Asphalt Roofing** | **2.D.4 Other** |
| **2.A.6 Road Paving with Asphalt** | |
| **2.A.7 Other** | **2.A.5 Other** |

### *2.1.7 2006 IPCC categories in the CRTs (Mineral Industry)*

**Table 2.2** – *Mineral Industry: tabular summary of correspondence between categories and subcategories in the 2006 IPCC Guidelines and the reporting structure of UNFCCC's CRTs*

| **2006 IPCC Guidelines** | **CRTs (UNFCCC reporting)** |
|---|---|
| | |
| **2.A Mineral Industry** | **2.A Mineral Industry** |
| **2.A.1 Cement Production** | **2.A.1 Cement Production** |
| **2.A.2 Lime Production** | **2.A.2 Lime Production** |
| **2.A.3 Glass Production** | **2.A.3 Glass Production** |
| **2.A.4 Other Process Uses of Carbonates** | **2.A.4 Other Process Uses of Carbonates** |
| 2.A.4.a Ceramics | 2.A.4.a Ceramics |
| 2.A.4.b Other Uses of Soda Ash | 2.A.4.b Other Uses of Soda Ash |
| 2.A.4.c Non Metallurgical Magnesia Production | 2.A.4.c Non-Metallurgical Magnesia Production |
| 2.A.4.d Other | 2.A.4.d Other |
| **2.A.5 Other** | |

## 2.2 Chemical Industry (2.B)

### *2.2.1 Overarching changes*

In the 2006 IPCC Guidelines, description of methodologies for the estimation of GHG emissions from the chemical industry were significantly expanded with many improvements. Overall, the new guidelines include enlarged descriptions of emission-related processes giving more information about their chemistry and technology aspects as well as more systematic guidance to avoid double counting of fuels used as a feedstock or reductant (including through a number of specific boxes).

In terms of categories' structure, emissions from Caprolactam, Glyoxal and Glyoxylic Acid Production (which were previously covered as part of "production of other chemicals", were added as a standalone source (2.B.4), so as Titanium Dioxide Production (2.B.6) and Petrochemical and Carbon Black Production (2.B.8), with the latter also including a number of specific subcategories. Also, 1996 IPCC Guidelines' Production of Halocarbons and $SF_6$ was renamed as Fluorochemical Production (2.B.9).

Moreover, several equations were revised and many decision trees and tables were added; and detailed Tier 1, Tier 2 and Tier 3 methods guidance was included.

**Box 2.5** – *Chemical Industry in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Chemical industry in the 2019 Refinement**

In the 2019 Refinement, changes and updates occurred to some subcategories within Chemical Industry, namely Nitric Acid Production and Fluorochemical Production, as described in specific boxes in the paragraphs below. It is also worth mentioning again the addition of the new category "Hydrogen Production", which is discussed extensively and includes guidance on definitions, double counting, completeness and cross-cutting allocation. No further changes occurred to the other subcategories within Chemical Industry. As highlighted for Mineral Industry, it is suggested that countries introduce domestic databases for point sources of emission with the view of having country specific/industrial facility specific information. These could be particularly useful, for instance, for Fluorochemical Production (2.B.9), as long as they are dedicated to F-gases. A more extensive and detailed list of all refinements made is provided in chapter 3 ("Chemical Industry Emissions") of "Annex 5: Mapping Tables" to the 2019 Refinement.

### *2.2.2 Ammonia Production (2.B.1)*

In Ammonia Production, specific improvements include a discussion of utilization of $CO_2$ in Urea Production (box 3.3, page 3.16) and a reallocation of emissions from urea use according to the sectors where urea is used (Energy, AFOLU). Only $CO_2$ recovered in urea and CCS can be subtracted from $CO_2$ emitted during ammonia production, and $CO_2$ recovered for industrial gas applications should not

be accounted for separately (as this is a relatively low volume short term use) (see Box 3.1). Furthermore, default total fuel requirements and default emission factors for ammonia production for different production processes (e.g. conventional reforming, excess air reforming, autothermal reforming, partial oxidation) were provided, compared to the generic emission factors that were included in the 1996 IPCC Guidelines.

### *2.2.3 Nitric Acid Production (2.B.2)*

In Nitric Acid Production, methods were refined with a Tier 1 based on national level production statistics multiplied by default emission factor, a Tier 2 based on national level production statistics multiplied by default emission factor while taking into account abatement technology; and a Tier 3 based on direct measurement or emissions monitoring systems (e.g. CEM). Moreover, $N_2O$ emission factors were updated for five production processes (Plants with Non-Selective Catalytic Reduction - NSCR, Plants with process-integrated or tailgas $N_2O$ destruction, Atmospheric pressure plants (low pressure), Medium pressure combustion plants, High pressure plants).

**Box 2.6** – *Nitric Acid Production in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Nitric Acid Production in the 2019 Refinement**

In the 2019 Refinement, improvements were made to nitric acid production, particularly within the chapter dealing with the choice of emission factors and involved all Tier 1, Tier 2 and Tier 3 methods to different extents. Specifically, production process categories (e.g., to include dual-pressure processes – see new table 3.3A) were updated as well as corresponding default emission factors for the Tier 2 method (Table 3.3).

### *2.2.4 Adipic Acid Production (2.B.3)*

In Adipic Acid Production, methods were refined with a Tier 1 based on national level production statistics multiplied by default emission factor, a Tier 2 based on national level production statistics multiplied by default emission factor while taking into account abatement technology; and a Tier 3 based on direct measurement or emissions monitoring systems. Emission factors were subject to minor updates compared to the previous guidelines.

### *2.2.5 Caprolactam, Glyoxal and Glyoxylic Acid Production (2.B.4)*

$N_2O$ emissions from Caprolactam, Glyoxal and Glyoxylic Acid Production were added as a new standalone source in the 2006 IPCC Guidelines, featuring methods, as in previous categories, that provide: a Tier 1 based on national level production statistics multiplied by default emission factor, a Tier 2 based on national level production statistics multiplied by default emission factor while taking into account abatement technology; and a Tier 3 based on direct measurement or emissions monitoring systems.

### *2.2.6 Carbide Production (2.B.5)*

In Carbide Production, a Tier 3 method based on plant-level data as well as guidance to develop plant-specific emission factors were provided. Moreover, ad hoc boxes on how to avoid double counting with the Energy sector and on allocation of emissions from lime production were included, partially updating previously available guidance.

### *2.2.7 Titanium Dioxide Production (2.B.6)*

$CO_2$ emissions from Titanium Dioxide Production were introduced as a new source in the 2006 IPCC Guidelines, including the identification of the chemical processes resulting into process GHG emissions, Tier 1 (based on national level production of titanium slag, synthetic rutile or rutile $TiO_2$ x default emission factor) and Tier 2 (based on plant-level data on the quantities of reducing agent and carbothermal input to derive emissions multiplied by default or plant-specific emission factors) methods, while Tier 3 is not available. A box on how to avoid double counting with the Energy sector is also provided.

### *2.2.8 Soda Ash Production (2.B.7)*

In the 1996 IPCC Guidelines, $CO_2$ emissions from Soda Ash Production and Use were allocated into the Mineral Industry chapter. In the 2006 IPCC Guidelines, the Production component was moved

under Chemical Industry with an independent category, while the Use component is still allocated under Mineral Industry (into the 2.A.4.b subcategory). The three Tiers methodology is presented, as well as a box on how to avoid double counting and an introduction of methodology for the synthetic ("Solvay") soda ash production process.

### *2.2.9 Petrochemical and Carbon Black Production (2.B.8)*

Emissions from Petrochemical and Carbon Black Production were included as a new standalone source in the 2006 IPCC Guidelines by covering, with a systematic description of Tier 1, 2 and 3 methodologies and several boxes describing related processes, the following subcategories: Methanol (2.B.8.a), Ethylene (2.B.8.b), Ethylene Dichloride and Vinyl Chloride Monomer (2.B.8.c), Ethylene Oxide (2.B.8.d), Acrylonitrile (2.B.8.e), Carbon Black (2.B.8.f). Feedstock-product flow diagrams are provided in a specific Annex (Annex 3.9A). Moreover, $CO_2$ and $CH_4$ emission factors have been added or updated. Finally, styrene production is no longer addressed in the 2006 IPCC Guidelines.

### *2.2.10 Fluorochemical Production (2.B.9)*

Emissions from Fluorochemical Production are included in the 2006 IPCC Guidelines as a new source category, corresponding to the previous category 2.E Production of halocarbons and sulphur hexafluoride (2.E.1 By-product emissions, 2.E.2 Fugitive emissions, 2.E.3 Other) in the 1996 IPCC Guidelines. Overall, more guidance is provided for estimating by-product and fugitive emissions from the production of other fluorinated compounds including hydrofluorocarbons (HFCs), sulphur hexafluoride ($SF_6$) and uranium hexafluoride ($UF_6$). Moreover, a methodology is provided for the calculation of trifluoromethane (HFC-23) emissions from chlorodifluoromethane (HCFC-22) production, as principal methods used within the industry. Specifically, in addition to a Tier 1 calculation of HFC-23 from HCFC-22 produced using a default emission factor, Tier 2 (based on efficiency-based material balance methods) and Tier 3 (based on continuous direct (3.a), proxy (3.b) and in-process measurements (3.c)) are provided.

**Box 2.7** – *Fluorochemical Production in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Fluorochemical Production in the 2019 Refinement**

In the 2019 Refinement, several revisions were made to the methodologies for fluorochemical production including on the choice of methods, emission factors and activity data. In particular, updates occurred to clarify the full range of emissions and their sources at fluorochemical production plants. Moreover, default emission factors for the Tier 1 method were updated, as well as the Tier 3 method to include emissions from equipment leaks and to provide more detail for estimating emissions from process vents. Many equations were added and some decision trees (for HFC-23 emissions and other emissions from production of fluorinated compounds) were updated.

### *2.2.11 Tabular summary of changes for Chemical Industry*

**Table 2.3** – *Chemical Industry: tabular summary of changes from the revised 1996 IPCC Guidelines to the 2006 IPCC Guidelines (highlighted in red are new categories/subcategories).*

| 1996 IPCC Guidelines | 2006 IPCC Guidelines |
|---|---|
| | |
| **2.B Chemical Industry** | **2.B Chemical Industry** |
| **2.B.1 Ammonia Production** | **2.B.1 Ammonia Production** |
| **2.B.2 Nitric Acid Production** | **2.B.2 Nitric Acid Production** |
| **2.B.3 Adipic Acid Production** | **2.B.3 Adipic Acid Production** |
| *2.A.4 Soda Ash Production and Use* | **2.B.4 Caprolactam, Glyoxal and Glyoxylic Acid Production** |
| **2.B.4 Carbide Production** | **2.B.5 Carbide Production** |
| | **2.B.6 Titanium Dioxide Production** |
| | **2.B.7 Soda Ash Production** |
| **2.B.5 Other** | **2.B.8 Petrochemical and Carbon Black Production** |
| | 2.B.8.a Methanol |
| | 2.B.8.b Ethylene |
| | 2.B.8.c Ethylene Dichloride and Vinyl Chloride |

| 1996 IPCC Guidelines | 2006 IPCC Guidelines |
|---|---|
| | Monomer |
| | 2.B.8.d Ethylene Oxide |
| | 2.B.8.e Acrylonitrile |
| | 2.B.8.f Carbon Black |
| 2.E Production of Halocarbons and Sulphur Hexafluoride | **2.B.9 Fluorochemical Production** |
| 2.E.1 By-product Emissions | 2.B.9.a By-product Emissions |
| 2.E.2 Fugitive Emissions | 2.B.9.b Fugitive Emissions |
| 2.E.3 Other | **2.B.10 Other** |

### *2.2.12 2006 IPCC categories in the CRTs (Chemical Industry)*

**Table 2.4** – *Chemical Industry: tabular summary of correspondence between categories and subcategories in the 2006 IPCC Guidelines and the reporting structure of UNFCCC's CRTs*

| 2006 IPCC Guidelines | CRTs (UNFCCC reporting) |
|---|---|
| | |
| **2.B Chemical Industry** | **2.B Chemical Industry** |
| **2.B.1 Ammonia Production** | **2.B.1 Ammonia Production** |
| **2.B.2 Nitric Acid Production** | **2.B.2 Nitric Acid Production** |
| **2.B.3 Adipic Acid Production** | **2.B.3 Adipic Acid Production** |
| **2.B.4 Caprolactam, Glyoxal and Glyoxylic Acid Production** | **2.B.4 Caprolactam, Glyoxal and Glyoxylic Acid Production** |
| | 2.B.4.a Caprolactam |
| | 2.B.4.b Glyoxal |
| | 2.B.4.c Glyoxylic Acid |
| **2.B.5 Carbide Production** | **2.B.5 Carbide Production** |
| | 2.B.5.a Silicon Carbide |
| | 2.B.5.b Calcium Carbide |
| **2.B.6 Titanium Dioxide Production** | **2.B.6 Titanium Dioxide Production** |
| **2.B.7 Soda Ash Production** | **2.B.7 Soda Ash Production** |
| **2.B.8 Petrochemical and Carbon Black Production** | **2.B.8 Petrochemical and Carbon Black Production** |
| 2.B.8.a Methanol | 2.B.8.a Methanol |
| 2.B.8.b Ethylene | 2.B.8.b Ethylene |
| 2.B.8.c Ethylene Dichloride and Vinyl Chloride Monomer | 2.B.8.c Ethylene Dichloride and Vinyl Chloride Monomer |
| 2.B.8.d Ethylene Oxide | 2.B.8.d Ethylene Oxide |
| 2.B.8.e Acrylonitrile | 2.B.8.e Acrylonitrile |
| 2.B.8.f Carbon Black | 2.B.8.f Carbon Black |
| 2.B.8.g Other | 2.B.8.g Other *(child nodes can be added)* |
| **2.B.9 Fluorochemical Production** | **2.B.9 Fluorochemical Production** |
| 2.B.9.a By-product Emissions | 2.B.9.a By-product Emissions |
| 2.B.9.b Fugitive Emissions | 2.B.9.b Fugitive Emissions |
| **2.B.10 Other** | **2.B.10 Other *(child nodes can be added)*** |

## 2.3 Metal production (2.C)

### *2.3.1 Overarching changes*

In the 2006 IPCC Guidelines, description of methodologies for the estimation of GHG emissions from metal production were significantly expanded with many improvements.

Overall, Tier 1 and 2 methodologies of iron and steel production are much more complex compared to the 1996 IPCC Guidelines, and now consider the carbon contents of all relevant input materials and

products rather than the previous simple product-based approaches. Similarly, Tier 2 and 3 methods are provided for primary Aluminium $CO_2$ emissions.

Additional guidance was provided for primary zinc, lead and magnesium production. Several decision trees were added. In terms of structure, Lead Production (2.C.5) and Zinc Production (2.C.5) were added as new source categories while Magnesium Production (2.C.4) consolidated guidance previously provided as "$SF_6$ Used in Aluminium and Magnesium Foundries".

**Box 2.8** – *Metal Production in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Metal Production in the 2019 Refinement**

In the 2019 Refinement, changes and updates occurred to some subcategories within Metal Production Industry, namely Iron & Steel and Metallurgical Coke Production and Primary Aluminium Production, as described in specific boxes in the paragraphs below. Rare Earths Production was added as a new subcategory with extensive guidance. No further changes occurred to the other subcategories within Metal Production (i.e. Ferroalloy Production, Magnesium Production, Lead Production, Zinc Production). A more extensive and detailed list of all refinements made is provided in chapter 4 ("Metal Industry Emissions") of "Annex 5: Mapping Tables" to the 2019 Refinement.

### *2.3.2 Iron and Steel and Metallurgical Coke Production (2.C.1)*

In this chapter, methodological issues and processes are largely addressed, including through specific figures for specific production processes which were included (Figures 4.1 to 4.5). The Tier 1 method in the 2006 IPCC Guidelines is much more detailed and needs additional data compared to the one in the 1996 IPCC Guidelines, as described in revised equations available.
New allocation rules were included, providing that all carbon used in blast furnaces, direct reduced iron (DRI), basic oxygen furnaces (BOF), electric arc furnaces (EAF) and open-hearth furnace (OHF) should be considered as process-related (i.e. reporting code 2.C.1) and all carbon used in the coke oven should be reported as energy (i.e. reporting code 1.A.1.c). See "Box 4 Avoiding double counting of carbon in steel and iron production" in the chapter 2 Fuel combustion (1.A.) for more details to avoid double counting between energy and process emissions.

Moreover, production-related, as well as blast furnace reducing agent $CO_2$ emission factors for Iron and Steel production were changed in the 2006 IPCC Guidelines. The Tier 2 methodology is an extension of the Tier 1 methodology for Iron and Steel Production, Direct Reduced Iron and Sinter Production. An additional table of carbon contents of detailed process materials for Iron and Steel and Coke Production is available, and new methodology for $CH_4$ from Blast furnaces, Coke and Sinter Production was introduced. Finally, the 2006 IPCC Guidelines now provide $CH_4$ default emission factors for Iron and Steel production (2.C.1).

**Box 2.9** – *Iron and Steel and Metallurgical Coke Production in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Iron and Steel and Metallurgical Coke Production in the 2019 Refinement**

In the 2019 Refinement, for Iron And Steel Production the methodological guidance was updated to include improved decision-trees and equations, a new Tier 2 method for methane emissions, new Tier 3a (plant-specific carbon balance) and Tier 3b (based on emission measurements) methods for carbon dioxide emissions, a new Tier 1 method for carbon dioxide emissions from flaring of process gases, and new methods to estimate nitrous oxide emissions including a Tier 1 method for emissions from flaring of process gases. For Metallurgical Coke Production, the guidance was updated to align it with the new methods presented in the Energy Volume for fugitive emissions, and to present new methods such as a Tier 1b simplified carbon balance method. Moreover, default emission factors have been extensively updated, and the Tier 2 material-specific carbon contents list has been extended and updated.

### *2.3.3 Ferroalloy Production (2.C.2)*

The 2006 IPCC Guidelines provide new and revised CO2 emission factors for reducing agents used in ferroalloys production. In addition, the 2006 IPCC Guidelines provide new CH4 emission factors for ferroalloys production by type of product (Tier 1) and technology (Tier 2).

### *2.3.4 Aluminium Production (2.C.3)*

In the 2006 IPCC Guidelines, Tier 1, Tier 2 and Tier 3 methods for Aluminium Production were maintained as they were in the previous guidelines, however, some emission factors were revised.

**Box 2.10** – *Primary Aluminium Production in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Aluminium Production in the 2019 Refinement**

In the 2019 Refinement, significant changes and updates were made, with the exception of choice of methods and emission factors for $CO_2$ emissions, for which the use of the relevant chapters in the 2006 IPCC Guidelines continue to be the suggested approach. Refinements in the guidance involved primarily the estimation of PFC emissions, including an update to the smelting technology classes, updated default emission factors for the Tier 1 method, new guidance for estimating emissions from low-voltage anode effects, updated default emission factors for the existing Tier 2 and Tier 3 (now Tier 2a and Tier 3a) methods for estimating emissions from high-voltage anode effects (termed "anode effects" in the 2006 IPCC Guidelines), new Tier 2b and Tier 3b methods for estimating emissions from high-voltage anode effects that better account for the impact of anode effect duration, and a new Tier 3DM method for facility-specific direct measurement of total PFC emissions. New guidance has also been added for estimating emissions from the production of alumina through the Bayer-Sinter and Nepheline processes.

### *2.3.5 Magnesium Production (2.C.4)*

The 2006 IPCC Guidelines introduced an emission factor for $SF_6$ (1 t $SF_6$/t Mg casting), while a method for $SF_6$ used for aluminium casting is no longer provided because it does not occur in practice. A Table featuring possible GHG emissions related to production and processing of magnesium is also provided (Table 4.18).

### *2.3.6 Tabular summary of changes for Metal Industry*

**Table 2.5** – *Metal Industry: tabular summary of changes from the revised 1996 IPCC Guidelines to the 2006 IPCC Guidelines (highlighted in red are new categories/subcategories, in green are consolidated ones).*

| 1996 IPCC Guidelines | 2006 IPCC Guidelines |
|---|---|
| | |
| **2.C Metal Production** | **2.C Metal Industry** |
| **2.C.1 Iron and Steel Production** | **2.C.1 Iron and Steel Production** |
| **2.C.2 Ferroalloys Production** | **2.C.2 Ferroalloys Production** |
| **2.C.3 Aluminium Production** | **2.C.3 Aluminium Production** |
| **2.C.4 SF6 Used in Aluminium and Magnesium Foundries** | **2.C.4 Magnesium Production** |
| | **2.C.5 Lead Production** |
| | **2.C.6 Zinc Production** |
| **2.C.5 Other** | **2.C.7 Other** |

### *2.3.7 2006 IPCC categories in the CRTs (Metal Industry)*

**Table 2.6** – *Metal Industry: tabular summary of correspondence between categories and subcategories in the 2006 IPCC Guidelines and the reporting structure of UNFCCC's CRTs*

| 2006 IPCC Guidelines | CRTs (UNFCCC reporting) |
|---|---|
| | |
| **2.C Metal Industry** | **2.C Metal Industry** |
| **2.C.1 Iron and Steel Production** | **2.C.1 Iron and Steel Production** |
| | 2.C.1.a. Steel |
| | 2.C.1.b. Pig iron |
| | 2.C.1.c. Direct reduced iron |
| | 2.C.1.d. Sinter |
| | 2.C.1.e. Pellet |
| | 2.C.1.f. Other *(child nodes can be added)* |
| **2.C.2 Ferroalloys Production** | **2.C.2 Ferroalloys Production** |

| 2006 IPCC Guidelines | CRTs (UNFCCC reporting) |
|---|---|
| **2.C.3 Aluminium Production** | **2.C.3 Aluminium Production** |
| **2.C.4 Magnesium Production** | **2.C.4 Magnesium Production** |
| **2.C.5 Lead Production** | **2.C.5 Lead Production** |
| **2.C.6 Zinc Production** | **2.C.6 Zinc Production** |
| **2.C.7 Other** | **2.C.7 Other *(child nodes can be added)*** |

## 2.4 Non-energy products from fuels and solvent use (2.D)

### *2.4.1 Overarching changes*

In the 2006 IPCC Guidelines, this category embodies and replaces what used to be an independent sector in the 1996 IPCC Guidelines, namely "Solvent and Other Product Use". The new Solvent Use category includes the previous ones Paint Applications, Degreasing and Dry Cleaning, and Chemical Products, Manufacture and Processing, addressing both indirect $CO_2$ and NMVOC, CO emissions. Moreover, $CO_2$ emissions from lubricant use and paraffin wax use, which were previously part of the Energy sector, are now included as part of IPPU. Overall, the guidance was significantly expanded.

### *2.4.2 Lubricant Use (2.D.1)*

The 2006 IPCC Guidelines provide method and default emission factor for Lubricant Use. Emissions from lubricants were previously covered under fuel combustion (1.A). The use of lubricants in engines is primarily for their lubricating properties. Therefore, associated emissions are considered as non-combustion emissions.

**Box 2.11** – *Emissions from Lubrificants*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Emissions from Lubrificants**

During the use of lubricants two fractions can be distinguished: one fraction is fully oxidised during use (resulting in direct $CO_2$ emissions), one fraction is not fully oxidised (resulting first in NMVOC and CO and then in indirect $CO_2$ emissions). Most of the emissions of lubricants occur after their use; waste oil handling emissions should be considered in the Waste Sector or in the Energy Sector (when energy is recovered). Emissions from 2-stroke engines (where the lubricant is mixed with another fuel and thus on purpose is co-combusted in the engine) should be considered as part of the combustion emissions in the Energy sector. Emissions from lubricants were previously covered under fuel combustion (1.A).

### *2.4.3 Paraffin Wax Use (2.D.2)*

The 2006 IPCC Guidelines provide method and default emission factor for Paraffin Wax Use. The source category includes such products as petroleum jelly, paraffin waxes and other waxes, including ozokerite. Emissions from paraffin waxes were previously covered under fuel combustion (1.A).

**Box 2.12** – *Emissions from Paraffin Waxes*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Emissions from Paraffin Waxes**

Emissions from the use of waxes derive primarily when the waxes or derivatives of paraffins are combusted during use (e.g., candles), and when they are incinerated with or without heat recovery or in wastewater treatment (for surfactants). When the waxes are combusted during use associated emissions are considered as non-energy emissions. In the cases of incineration and wastewater treatment the emissions should be reported in the Energy or Waste Sectors, respectively.

### *2.4.4 Solvent Use (2.D.3)*

The 2006 IPCC Guidelines provide a default value for the fossil carbon content fraction of NMVOC for the calculation of indirect $CO_2$ emissions, since solvents, while not being a significant source of direct GHG emissions, cause indirect $CO_2$ emissions as being a source of ozone precursors (NMVOC).

### 2.4.5 Other (2.D.4)

This source category comprises the non-combustion emissions from the production of asphalt in asphalt plants other than refineries and its application (such as paving and roofing operations as well as subsequent releases from the surfaces), previously included in 2.A. The 2006 IPCC Guidelines provide a method and default emission factor. For asphalt production and use only indirect $CO_2$ from NMVOC is relevant. Emissions from fuel combustion needed to supply heat to the asphalt processes (production or heating of the asphalt mix) are covered under the Energy Sector.

### 2.4.6 Tabular summary of changes for Non-Energy Products from Fuels and Solvent Use

**Table 2.7** – *Non-Energy Products from Fuels and Solvent Use: tabular summary of changes from the Revised 1996 IPCC Guidelines to the 2006 IPCC Guidelines (highlighted in red are new categories/subcategories, in green are consolidated ones).*

<table>
<tr><th>1996 IPCC Guidelines</th><th>2006 IPCC Guidelines</th></tr>
<tr><td></td><td></td></tr>
<tr><td>3 Solvent and Other Product Use</td><td>2.D Non-Energy Products from Fuels and Solvent Use</td></tr>
<tr><td></td><td>2.D.1 Lubricant Use</td></tr>
<tr><td></td><td>2.D.2 Paraffin Wax Use</td></tr>
<tr><td>3.A Paint Applications</td><td rowspan="4">2.D.3 Solvent Use</td></tr>
<tr><td>3.B Degreasing and Dry Cleaning</td></tr>
<tr><td>3.C Chemical Products, Manufacture and Processing</td></tr>
</table>

### 2.4.7 2006 IPCC categories in the CRTs (Non-Energy Products from Fuels and Solvent Use)

**Table 2.8** – *Non-Energy Products from Fuels and Solvent Use: tabular summary of correspondence between categories and subcategories in the 2006 IPCC Guidelines and the reporting structure of UNFCCC's CRTs*

<table>
<tr><th>2006 IPCC Guidelines</th><th>CRTs (UNFCCC reporting)</th></tr>
<tr><td></td><td></td></tr>
<tr><td>2.D Non-Energy Products from Fuels and Solvent Use</td><td>2.D Non-Energy Products from Fuels and Solvent Use</td></tr>
<tr><td>2.D.1 Lubricant Use</td><td>2.D.1 Lubricant Use</td></tr>
<tr><td>2.D.2 Paraffin Wax Use</td><td>2.D.2 Paraffin Wax Use</td></tr>
<tr><td>2.D.3 Solvent Use</td><td rowspan="2">2.D.3 Other (child nodes can be added)</td></tr>
<tr><td>2.D.4 Other</td></tr>
</table>

## 2.5 Electronics Industry emissions (2.E)

### 2.5.1 Overarching changes

This new source category corresponds to the previous category 2.F.7 Semiconductor Manufacture. It is now split into products, corresponding to specific subcategories: in addition to Semiconductor Manufacture (2.E.1), which in the 2006 IPCC Guidelines include NF3 as a new gas, it also includes TFT Flat Panels Display (2.E.2) and Photovoltaic Manufacturing (2.E.3) and Heat Transfer Fluid (2.E.4). Besides this addition in scope of the category, the 2006 IPCC Guidelines include methods for additional GHG gases previously not considered.

For Etching and CVD Cleaning (in all three product groups), three Tier methods are available with Tier 1 featuring a new methodology based on area of substrate (instead of sales data of FC gases); Tier 2a and 2b, now considering respectively by-product emissions of $C_2F_6$, $CHF_3$ and $C_3F_8$ and by-product emissions from the use of other halogenated gases ($C_4F_6$, $C_5F_8$, $C_4F_8O$, $CH_2F_2$, and of the use of non-GHGs $F_2$ and $COF_2$); and Tier 3 with a new methodology using company-specific parameters for all processes.

**Box 2.13** – *Electronics Industry in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Electronics Industry in the 2019 Refinement**

For this category, in the 2019 Refinement several methodological changes were introduced. New guidance was provided on tracking gas consumption and on apportioning use to different process types. Six revised Tier methods (1, 2a, 2b, 2c, 3a, 3b) are included for Gaseous Fluorinated compounds and $N_2O$, compared to the previous four in the 2006 IPCC Guidelines.
Tier 1 default emissions factors (EFs) for semiconductor and display manufacturing have been updated to account for technological advancements and for the use of a broader basket of FC gases and fluorinated liquids. In addition, default EFs for MEMS have been introduced.

Other changes include updated and new Tier 2 methods that account for the size of manufactured wafers in semiconductor manufacturing, a new Tier 3b method for estimating emissions by developing facility-specific emission factors at the stack level, new guidance on adapting Tier 2 methods to account for technological changes, new guidance for the sub-sector microelectromechanical systems (MEMS) – which is included as a new standalone subcategory (2.E.4) – and updates to the default emission factors for Tier 1 and Tier 2 methods, including an expanded list of input gases, by-products, and fluorinated liquids.

A more extensive and detailed list of all refinements made is provided in chapter 6 ("Electronic Industry Emissions") of "Annex 5: Mapping Tables" to the 2019 Refinement.

### *2.5.2 Tabular summary of changes for Electronic Industry*

**Table 2.9** – *Electronic Industry: tabular summary of changes from the revised 1996 IPCC Guidelines to the 2006 IPCC Guidelines (highlighted in red are new categories/subcategories, in green are consolidated ones).*

| 1996 IPCC Guidelines | 2006 IPCC Guidelines |
|---|---|
| | |
| **2.F Solvent and Other Product Use** | **2.E Electronic Industry** |
| 2.F.7 Semiconductor Manufacture | **2.E.1 Integrated Circuit or Semiconductor** |
| | **2.E.2 TFT Flat Panel Display** |
| | **2.E.3 Photovoltaics** |
| | **2.E.4 Heat Transfer Fluid** |
| | **2.E.5 Other** |

### *2.5.3 2006 IPCC categories in the CRTs (Electronic Industry)*

**Table 2.10** – *Electronic Industry: tabular summary of correspondence between categories and subcategories in the 2006 IPCC Guidelines and the reporting structure of UNFCCC's CRTs*

| 2006 IPCC Guidelines | CRTs (UNFCCC reporting) |
|---|---|
| | |
| **2.E Electronic Industry** | **2.E Electronic Industry** |
| **2.E.1 Integrated Circuit or Semiconductor** | **2.E.1 Integrated Circuit or Semiconductor** |
| **2.E.2 TFT Flat Panel Display** | **2.E.2 TFT Flat Panel Display** |
| **2.E.3 Photovoltaics** | **2.E.3 Photovoltaics** |
| **2.E.4 Heat Transfer Fluid** | **2.E.4 Heat Transfer Fluid** |
| **2.E.5 Other** | **2.E.5 Other *(child nodes can be added)*** |

## 2.6 Emissions of fluorinated substitutes for ozone depleting substances (ODS) (2.F)

### *2.6.1 Overarching changes*

In the 2006 IPCC Guidelines, emissions of fluorinated substitutes for ozone depleting substances follow a very similar structure of that in the 1996 IPCC Guidelines: Stationary and mobile refrigeration has been unified and the new category include Domestic, Commercial and Industrial Refrigeration, Transport Refrigeration, Stationary Air Conditioning and Mobile Air Conditioning.

In the new guidelines, potential emissions are no longer considered as Tier 1, but the method is described (in annex 2, vol. 3). The new Tier 1 method is either based on emission factor or on mass balance and it is relevant only if aggregated information on appliances is available. The choice of a Tier 1a or 2a (EF based), or between a Tier 1b or 2b (mass balance) depends on the level of aggregation of input data.

A few improvements are listed in the next paragraphs for Refrigeration and Air Conditioning (2.F.1), Foam Blowing (2.F.2) and Fire Protection (2.F.3); while no relevant changes occurred to Aerosols (2.F.4), Solvents (2.F.5) and Other Applications (2.F.6).

**Box 2.14** – *Emissions of fluorinated substitutes for ozone depleting substances in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Emissions of fluorinated substitutes for ozone depleting substances in the 2019 Refinement**

In this category, some changes occurred in the 2019 Refinement involving the application areas covered and general methodological issues for all ODS substitute, particularly on the choice of method. Further specific improvements were made to Refrigeration and Air Conditioning, as described in a specific box in the relevant paragraph below. A more extensive and detailed list of all refinements made is provided in chapter 7 ("Emissions of fluorinated substitutes for ozone depleting substances") of "Annex 5: Mapping Tables" to the 2019 Refinement.

### *2.6.2 Refrigeration and Air Conditioning (2.F.1)*

In the new guidelines, Tier 2a also considers refrigerant management of containers. Tier 2b is the same as in the IPCC Good Practice Guidance. Moreover, lifetime and operating emission default values increased in the new guidelines, mainly for developing countries.

**Box 2.15** – *Refrigeration and Air Conditioning in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Refrigeration and Air Conditioning in the 2019 Refinement**

For refrigeration and air conditioning, some improvements occurred on the choice of methods, emission factors and activity data. New guidance on building an HFC emissions inventory (including guidance on data sources and on establishing the existing bank of HFCs) is provided, as well as new and updated tables regarding the identity and distribution of substitutes for ozone depleting substances (ODS) by application and by substance for both developing and developed countries. Changes also occurred in the application of Tier 2 methods.

### *2.6.3 Foam Blowing (2.F.2)*

In the 2006 IPCC Guidelines, some default emission factors for first year losses changed (some are now higher, some are lower).

### *2.6.4 Fire Protection (2.F.3)*

For Fire Protection, a revised methodology is available in the 2006 IPCC Guidelines being based on banks, while the previous was based on sales (emissions are equal to the amount refilled during service of fire protection equipment, plus end-of-life emissions). Furthermore, emission factor was revised with the provision of a range compared to the old default.

### 2.6.5 Tabular summary of changes for Product Uses as Substitutes for ODS

**Table 2.11** – *Product Uses as Substitutes for ODS: tabular summary of changes from the revised 1996 IPCC Guidelines to the 2006 IPCC Guidelines (highlighted in blue are disaggregated categories/subcategories).*

| 1996 IPCC Guidelines | 2006 IPCC Guidelines |
|---|---|
| | |
| | **2.F Product Uses as Substitutes for ODS** |
| **2.F.1 Refrigeration and Air Conditioning Equipment** | **2.F.1 Refrigeration and Air Conditioning** |
| | 2.F.1.a Refrigeration and Stationary Air Conditioning |
| | 2.F.1.b Mobile Air Conditioning |
| **2.F.2 Foam Blowing** | **2.F.2 Foam Blowing Agents** |
| **2.F.3 Fire Extinguishers** | **2.F.3 Fire Protection** |
| **2.F.4 Aerosols / Metered Dose Inhalers** | **2.F.4 Aerosols** |
| **2.F.5 Solvents** | **2.F.5 Solvents** |
| **2.F.6 Other Applications using ODS Substitutes** | **2.F.6 Other Applications** |

### 2.6.6 2006 IPCC categories in the CRTs (Product Uses as Substitutes for ODS)

**Table 2.12** – *Product Uses as Substitutes for ODS: tabular summary of correspondence between categories and subcategories in the 2006 IPCC Guidelines and the reporting structure of UNFCCC's CRTs*

| 2006 IPCC Guidelines | CRTs (UNFCCC reporting) |
|---|---|
| | |
| **2.F Product Uses as Substitutes for ODS** | **2.F Product Uses as Substitutes for ODS** |
| **2.F.1 Refrigeration and Air Conditioning** | **2.F.1 Refrigeration and Air Conditioning** |
| 2.F.1.a Refrigeration and Stationary Air Conditioning | 2.F.1.a. Commercial refrigeration |
| | 2.F.1.b. Domestic refrigeration |
| | 2.F.1.c. Industrial refrigeration |
| | 2.F.1.d. Transport refrigeration |
| | 2.F.1.f. Stationary air-conditioning |
| 2.F.1.b Mobile Air Conditioning | 2.F.1.e. Mobile air-conditioning |
| **2.F.2 Foam Blowing Agents** | **2.F.2 Foam Blowing Agents** |
| | 2.F.2.a. Closed cells |
| | 2.F.2.b. Open cells |
| **2.F.3 Fire Protection** | **2.F.3 Fire Protection** |
| **2.F.4 Aerosols** | **2.F.4 Aerosols** |
| | 2.F.4.a. Metered dose inhalers |
| | 2.F.4.b. Other *(child nodes can be added)* |
| **2.F.5 Solvents** | **2.F.5 Solvents** |
| **2.F.6 Other Applications** | **2.F.6 Other Applications** |
| | 2.F.6.a. Emissive |
| | 2.F.6.b. Contained |

## 2.7 Other product manufacture and use (2.G)

### 2.7.1 Overarching changes

In the 2006 IPCC Guidelines, Other Product Manufacture and Use is a new category, although it is the result of several previous categories/subcategories being consolidated or disaggregated (including emissions from the previous categories 2.F.8 Electrical equipment, 2.F.9 Other, 2.D Other production, and 3.D Other), with some further added such as SF6 and PFCs from Other Product Uses (2.G.2).

**Box 2.16** – *Other Product Manufacture and Use in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Other Product Manufacture and Use in the 2019 Refinement**

In the 2019 Refinement, some changes occurred to the choice of method for military and other applications. New guidance was provided for waterproofing of electronic circuits and for Textile, carpet, leather and paper fluorinated treatment emissions. A more extensive and detailed list of all refinements made is provided in chapter 8 ("Other Product Manufacture and Use") of "Annex 5: Mapping Tables" to the 2019 Refinement.

### *2.7.2 Emissions of $SF_6$ and PFC from Electrical equipment (2.G.1)*

The 2006 IPCC Guidelines also provide for reporting of PFC emissions, while previously only $SF_6$ emissions were reported under Electrical equipment (2.F.8). The new Tier 1 method for $SF_6$, using default emission factors, corresponds to the Tier 2a method of IPCC Good Practice Guidance. Default emission factors were updated.

### *2.7.3 Use of $SF_6$ and PFCs in other products (2.G.2)*

This is a new source, in the previous guidelines there was no methodology nor default emission factors available. The 2006 IPCC Guidelines distinguish between the sub-categories "Military applications", "Accelerators" and "Other".

### *2.7.4 $N_2O$ from Product Uses (2.G.3)*

On this category, the 2006 IPCC Guidelines include for the first time a simple method and default emission factors to calculate $N_2O$ emissions from product use.

### *2.7.5 Tabular summary of changes for Other Product Manufacture and Use*

**Table 2.13** – *Other Product Manufacture and Use: tabular summary of changes from the revised 1996 IPCC Guidelines to the 2006 IPCC Guidelines (highlighted in blue are disaggregated categories/subcategories, in green are consolidated ones and in red are new ones).*

| 1996 IPCC Guidelines | 2006 IPCC Guidelines |
|---|---|
| | |
| | **2.G Other Product Manufacture and Use** |
| **2.F.8 Electrical Equipment** | **2.G.1 Electrical Equipment** |
| | 2.G.1.a Manufacture of Electrical Equipment |
| | 2.G.1.b Use of Electrical Equipment |
| | 2.G.1.c Disposal of Electrical Equipment |
| | **2.G.2 $SF_6$ and PFCs from Other Product Uses** |
| | 2.G.2.a Military Applications |
| | 2.G.2.b Accelerators |
| | 2.G.2.c Other |
| **3.D Other** | **2.G.3 $N_2O$ from Product Uses** |
| **3.D.1 Use of $N_2O$ for Anaesthesia*** | 2.G.3.a Medical Applications |
| **3.D.2 $N_2O$ from Aerosol Cans*** | 2.G.3.b Propellant for Pressure and Aerosol Products |
| **3.D.3 $N_2O$ from Fire Extinguishers*** | 2.G.3.c Other |
| **3.D.4 Other Use of $N_2O$*** | |
| **3.D.5 Other*** | |
| **2.G Other** | **2.G.4 Other** |

**subcategories which were not mandatory in the 1996 IPCC Guidelines.*

### *2.7.6 2006 IPCC categories in the CRTs (Other Product Manufacture and Use)*

**Table 2.14** – *Other Product Manufacture and Use: tabular summary of correspondence between categories and subcategories in the 2006 IPCC Guidelines and the reporting structure of UNFCCC's CRTs*

| **2006 IPCC Guidelines** | **CRTs (UNFCCC reporting)** |
|---|---|
| | |
| **2.G Other Product Manufacture and Use** | **2.G Other Product Manufacture and Use** |
| **2.G.1 Electrical Equipment** | **2.G.1 Electrical Equipment *(child nodes can be added)*** |
| 2.G.1.a Manufacture of Electrical Equipment | |
| 2.G.1.b Use of Electrical Equipment | |
| 2.G.1.c Disposal of Electrical Equipment | |
| **2.G.2 $SF_6$ and PFCs from Other Product Uses** | **2.G.2 $SF_6$ and PFCs from Other Product Uses** |
| 2.G.2.a Military Applications | 2.G.2.a. Military applications |
| 2.G.2.b Accelerators | 2.G.2.b. Accelerators |
| 2.G.2.c Other | 2.G.2.c. Soundproof windows |
| | 2.G.2.d. Adiabatic properties: shoes and tyres |
| | 2.G.2.e. Other *(child nodes can be added)* |
| **2.G.3 $N_2O$ from Product Uses** | **2.G.3 $N_2O$ from Product Uses** |
| 2.G.3.a Medical Applications | 2.G.3.a Medical Applications |
| 2.G.3.b Propellant for Pressure and Aerosol Products | 2.G.3.b Other *(child nodes can be added)* |
| 2.G.3.c Other | |
| **2.G.4 Other** | **2.G.4 Other *(child nodes can be added)*** |

# 3 AGRICULTURE, FORESTRY AND OTHER LAND USE (AFOLU)

## Overview

In the 2006 IPCC Guidelines, the **Agriculture and LULUCF sectors** are included **into one IPCC chapter named "AFOLU"**. This integration aimed to enhance the data collection, being the 2 sectors strictly interlinked for several data and parameters, enabling a more consistent use of data, especially for higher tier methods. Nevertheless, in the UNFCCC reporting, the Agriculture and the LULUCF sectors are separated; in Table 1, the allocation of AFOLU categories in the two sectors, i.e. Agriculture and LULUCF, are shown; in the same table, GHGs to be reported for each category are also included. In the Agriculture sector, $CH_4$ and $N_2O$ emissions are reported, mainly related to biological processes, while $CO_2$ emissions and removals are key in the LULUCF sector.

**Table 3.1** – *CRF categories for the Agriculture and LULUCF sectors*

| AGRICULTURE | GHGs | LULUCF | GHGs |
|---|---|---|---|
| Enteric fermentation | $CH_4$ | Forest Land | $CO_2$, $CH_4$, $N_2O$ |
| Manure management | $CH_4$, $N_2O$ | Cropland | $CO_2$, $CH_4$, $N_2O$ |
| Rice cultivation | $CH_4$ | Grassland | $CO_2$, $CH_4$, $N_2O$ |
| Agricultural soils | $N_2O$ | Wetlands | $CO_2$, $CH_4$, $N_2O$ |
| Prescribed burning of savannas | $CH_4$, $N_2O$ | Settlements | $CO_2$, $CH_4$, $N_2O$ |
| Field burning of agricultural residues | $CH_4$, $N_2O$ | Other land | $CO_2$, $CH_4$, $N_2O$ |
| Liming | $CO_2$ | Harvested wood products | $CO_2$ |
| Urea application | $CO_2$ | | |
| Other carbon-containing fertilizers | $CO_2$ | | |

Accordingly, in line with the scope of this guide which is aimed at facilitating countries' reporting in the framework of UNFCCC arrangements, changes and improvements affecting the two AFOLU sectors are discussed in two distinct sections (Agriculture, LULUCF). Nevertheless, a summary of the main improvements in the 2006 IPCC Guidelines for the two AFOLU sectors is outlined below (Box 3.1).

**Box 3.1** – *Summary of main improvements in the 2006 IPCC Guidelines for the AFOLU sectors*

| **MAIN SPECIFIC IMPROVEMENTS IN THE AGRICULTURE AND LULUCF SECTORS UNDER AFOLU** | |
|---|---|
| Changes: | **LULUCF**<br>- Adoption of six land use categories, i.e., Forest Land, Cropland, Grassland, Wetlands, Settlements, and Other Land, further sub-divided into land remaining in the same category and land converted from one category to another.<br>- Managed land is used as a proxy for identifying anthropogenic emissions by sources and removals by sinks.<br>- Reporting on all emissions by sources and removals by sinks from managed lands, which are considered to be anthropogenic, while emissions and removals for unmanaged lands are not reported.<br>- Adoption of three hierarchical tiers of methods that range from default emission factors and simple equations to the use of country-specific data and models to accommodate national circumstances.<br>- Incorporation of key category analysis for land-use categories, C pools, and $CO_2$ and non-$CO_2$ greenhouse gas emissions.<br>- Greater consistency in land area classification for selecting appropriate emission and stock change factors and activity data. |
| Added: | **Agriculture**<br>- Full sectoral coverage of indirect $N_2O$ emissions, including from manure management.<br>- Guidance for the estimation of $CO_2$ emissions from urea application as a fertilizer.<br>- Nitrous oxide from nitrogen mineralization associated with loss of soil organic matter resulting from change of land use or management of mineral soils (direct and indirect $N_2O$ emissions from managed soils).<br>- N additions applied to soils from other organic fertilizers and compost.<br>**LULUCF**<br>- Estimation methods for stock changes in the biomass, dead organic matter and soil pools, in all land-use categories and generic methods for greenhouse gas emissions from biomass burning.<br>- Estimation methods for C stock changes associated with harvested wood products (HWP). |
| Revised: | **Agriculture**<br>- Revision of methodology and emission factors for rice cultivation.<br>- Revision of methodology and emission factors from agricultural soils.<br>- Removal of biological nitrogen fixation as a direct source of $N_2O$ from agricultural soils because of the lack of evidence of significant emissions arising from the fixation process. |

# SECTION I – AGRICULTURE

## Overview

The emission categories where improvements have been implemented, considering the 2006 IPCC Guidelines, are:

- Enteric fermentation (3.A): update of parameters;
- Manure management (3.B): update of parameters and inclusion methodology for indirect $N_2O$ emissions;
- Rice cultivation (3.C): improvement of methodology;
- Agricultural soils (3.D): improvement of methodology;
- Urea application (3.H): inclusion of guidance for $CO_2$ emissions.

As stated in the 2006 IPCC Guidelines, in order to estimate emissions from livestock, it is first necessary to collect data on the annual population of the relevant animal categories present in the country, possibly with details of subcategories. More details on the estimated average annual population can be found in the 2006 IPCC Guidelines.

**Box 3.2** – *The impact of the 2019 Refinement on Agriculture categories*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**The impact of the 2019 Refinement on Agriculture categories**

The 2019 Refinement impacts default parameters in most of the main agriculture categories, however the use of country-specific parameters varies by category (high for enteric fermentation, low for soils). The largest impacts in both absolute and relative terms are likely to be on $N_2O$ emissions from managed soils, followed by $N_2O$ emissions from manure management. Specific changes are highlighted under the specific categories in the next chapters. While the 2019 Refinement not being yet mandatory for UNFCCC reporting, it is suggested that inventory compilers take such improvements into account as they may facilitate reporting.

## 3.1 Tabular summary of changes for Agriculture categories

**Table 3.2 –** Agriculture categories: tabular summary of changes from the revised 1996 IPCC Guidelines to the 2006 IPCC Guidelines *(highlighted in red are new categories/subcategories)*.

| **1996 IPCC Guidelines** | **2006 IPCC Guidelines** |
|---|---|
| | |
| **Enteric fermentation** | **Enteric fermentation** |
| **$CH_4$ from manure management** | **$CH_4$ from manure management** |
| **$N_2O$ from manure management** | **Direct $N_2O$ from manure management** |
| | **Indirect $N_2O$ from manure management** |
| **Rice cultivation** | **Rice cultivation** |
| **Agricultural soils** | **Direct $N_2O$ from managed soils** |
| | **Indirect $N_2O$ from managed soils** |
| **Prescribed burning of savannas** | **Emissions from biomass burning** |
| **Burning of agricultural residues** | |
| | **Liming*** |
| | **Urea application*** |

**these categories were previously included in the LULUCF sector following the 2003 IPCC Good Practice Guidance for LULUCF*

## 3.2 2006 IPCC categories in the CRTs

The following table shows the complete list of emission categories that must be reported in the CRTs.

**Table 3.3** – *Agriculture reporting codes in the CRTs*

| **AGRICULTURE** |
|---|
| **3.A Enteric Fermentation** |
| **3.A.1 Cattle** |
| ***Option A*** |
| 3.A.1.a. Dairy cattle |
| 3.A.1.b. Non-dairy cattle |
| ***Option B (country-specific)*** |
| 3.A.1.a. Other (as specified in table 3.A) |
| **3.A.2 Sheep** |
| 3.A.2.a. Other *(child nodes can be added)* |
| **3.A.3 Swine** |
| 3.A.3.a. Other *(child nodes can be added)* |
| **3.A.4 Other livestock *(child nodes can be added)*** |
| **3.B Manure Management** |
| **3.B.1 Cattle** |
| ***Option A*** |
| 3.B.1.a. Dairy cattle |
| 3.B.1.b. Non-dairy cattle |
| ***Option B (country-specific)*** |
| 3.B.1.a. Other (as specified in table 3.B) |
| **3.B.2 Sheep** |
| 3.B.2.a. Other *(child nodes can be added)* |
| **3.B.3 Swine** |
| 3.B.3.a. Other *(child nodes can be added)* |
| **3.B.4 Other livestock** |
| **3.B.5 Indirect $N_2O$ emissions** |
| **3.C Rice cultivation** |
| **3.C.1. Irrigated** |
| 3.C.1.a. Continuously flooded |
| 3.C.1.b. Intermittently flooded |
| 3.C.1.b.i. Single aeration |
| 3.C.1.b.ii.Multiple aeration |
| **3.C.2. Rain-fed** |
| 3.C.2.a. Flood-prone |
| 3.C.2.b. Drought-prone |
| **3.C.3. Deep water** |
| 3.C.3.a. Water depth 50–100 cm |
| 3.C.3.b. Water depth > 100 cm |
| **3.C.4. Other *(child nodes can be added)*** |
| **3.D Agricultural soils** |
| **3.D.1. Direct $N_2O$ emissions from managed soils** |
| 3.D.1.a. Inorganic N fertilizers |
| 3.D.1.b. Organic N fertilizers |
| 3.D.1.b.i. Animal manure applied to soils |
| 3.D.1.b.ii. Sewage sludge applied to soils |
| 3.D.1.b.iii. Other organic fertilizers applied to soils |

| AGRICULTURE |
|---|
| 3.D.1.c. Urine and dung deposited by grazing animals |
| 3.D.1.d. Crop residues |
| 3.D.1.e. Mineralization/immobilization associated with loss/gain of soil organic matter |
| 3.D.1.f. Cultivation of organic soils (i.e. histosols) |
| 3.D.1.g. Other |
| **3.D.2. Indirect $N_2O$ Emissions from managed soils** |
| 3.D.2.a. Atmospheric deposition[6] |
| 3.D.2.b. Nitrogen leaching and run-off |
| **3.E Prescribed burning of savannas** |
| **3.E.1. Forest land *(specify ecological zone)*** |
| **3.E.2. Grassland *(specify ecological zone)*** |
| **3.F Field burning of agricultural residues** |
| **3.F.1. Cereals** |
| 3.F.1.a. Wheat |
| 3.F.1.b. Barley |
| 3.F.1.c. Maize |
| 3.F.1.d. Other *(child nodes can be added)* |
| **3.F.2. Pulses** |
| 3.F.2.a. Other *(child nodes can be added)* |
| **3.F.3. Tubers and roots** |
| 3.F.3.a. Other *(child nodes can be added)* |
| **3.F.4. Sugar cane** |
| **3.F.5. Other *(child nodes can be added)*** |
| **3.G Liming** |
| **3.G.1. Limestone $CaCO_3$** |
| **3.G.2. Dolomite $CaMg(CO_3)_2$** |
| **3.H Urea application** |
| **3.I Other carbon-containing fertilizers** |
| **3.J Other *(child nodes can be added)*** |

* Livestock categories should be specified as needed by using additional lines (e.g. llamas, alpacas, deer, reindeers, rabbits, fur-bearing animals, fox and raccoon, mink and polecat, ostriches, etc.)

## 3.3 Enteric fermentation (3.A)

### *3.3.1 Overarching changes*

For cattle, buffalo and sheep categories, a Tier 2 method for the estimation of enteric fermentation emissions had already been updated (for cattle) and developed (for buffalo and sheep) in the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC GPG). However, default emission factors for developed and developing countries are provided, separately, in the 2006 IPCC Guidelines. Tier 1 emission factors and average weight values for deer and alpacas have also been included.

**Box 3.3** – *Practical requirements for data collection in Enteric Fermentation*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Practical requirements for data collection in Enteric Fermentation**

In the 2006 IPCC Guidelines, as regards the estimation of **energy for activity** for cattle, buffalo and sheep (Equation 10.4 and 10.5 – Volume 4, Chapter 10), the percentage of animals grazing and the days or months of grazing per year should be considered. These data will be needed to calculate an average energy for activity value, if a mixture of the feeding situations occurs, as reported in the 2006 IPCC Guidelines.

When calculating **energy for pregnancy** ($NE_p$) for cattle, buffalo and sheep (Equation 10.13 – Volume 4, Chapter 10), the percentage of mature females that actually go through gestation in a year should be taken into account to estimate a weighted value for $NE_p$, as stated in the 2006 IPCC Guidelines.

**Box 3.4** – *Improvements for enteric fermentation in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Improvements for enteric fermentation in the 2019 Refinement**

In the 2019 Refinement, Tier 1 EFs for cattle, buffalo, sheep and goats have been updated, and a split by high/low productivity systems was operated. Additional values were included to apply the Tier 2 method for goats. Tier 2 $Y_m$ values have also been updated for cattle and sheep. The impacts vary by livestock type and Tier.

### *3.3.2 Cattle (3.A.1)*

Enteric fermentation default emission factors for cattle (both "dairy" and "other cattle") have been revised with a general increase in their values for all regions.

In particular, for dairy cattle $CH_4$ emissions, a Tier 2 method has been implemented and some critical parameters have been updated in the 2006 IPCC guidelines:

- reduced estimations: feed digestibility (more detailed information and ranges of values associated with different types of diets are available);
- increased estimations: coefficients for calculating net energy for maintenance - $Cf_i$ (change from 0.335 to 0.386 MJ $d^{-1}$ $kg^{-1}$); coefficient corresponding to animal's feeding situation – $C_a$ (for grazing large areas change from 36% to 37%); pregnancy coefficient - $C_{pregnancy}$ (change from 7.5% to 10%);
- updated equation for the estimation of the energy for growth;
- corrected equation for the estimation of gross energy (GE);
- integration of a simplified Tier 2 method for the estimation of feed intake for cattle category.

## 3.4 Manure management (3.B)

### *3.4.1 Overarching changes*

In the 2006 IPCC Guidelines, changes occurred in $CH_4$ emission factors for cattle, swine and buffalo. Moreover, the livestock categories are more disaggregated and $CH_4$ emission factors are listed by the annual average temperature for the climate zone with temperature ranges subdivided by 1°C degree increment. These Tier 1 emission factors are more difficult to implement due to the higher disaggregation of activity data required. Other changes include: updating of emission factors for other animal categories (other than cattle, swine and buffalo); availability of emission factors for poultry subcategories; and inclusion of emission factors for deer, reindeer, rabbits, fur animals.

As regards the Tier 2 emission factors, the volatile solid (VS) excretion rate is now estimated also considering the urinary energy expressed as fraction of GE. Methane conversion factor (MCF) parameters have been updated for emission estimations for all livestock categories: MCF values for estimation of $CH_4$ emissions are presented as a function of average annual temperature with temperature ranges subdivided by 1°C steps and for manure management systems. For swine category, more maximum methane-producing capacity of the manure ($B_o$) values are available by animal category (market swine and breeding swine) and by region. Data to estimate Tier 2 emission factors are now also available for other animal categories (poultry subcategories, deer, reindeer, rabbits, fur animals, ostriches). Considering manure management systems, new systems are now considered, such as deep bedding, different types of composting, poultry with and without bedding, aerobic treatment.

Default emission factors for direct $N_2O$ emissions from manure management have been updated for liquid/slurry, anaerobic lagoon, solid storage and pasture/range/paddock. For other systems (pit storage below animal confinements, anaerobic digester, cattle and swine deep bedding, composting, poultry manure with litter and without litter, aerobic treatment), default emission factors have been added in the 2006 IPCC Guidelines.
The 2006 IPCC Guidelines further increased the disaggregation of the manure management systems, which can increase the challenges for countries to obtain appropriate activity data, which were already a constraint in the implementation of the guidance from IPCC GPG for manure management.
In the 2006 IPCC Guidelines, there are two methods (Tier 1 and 2) to estimate the annual nitrogen excretion (Nex). For Tier 1, Nex is calculated from the default values of nitrogen excretion rate (kg N (1,000 kg animal mass)$^{-1}$ day$^{-1}$) and from the average weight per animal category. For Tier 2, Nex depends on the total annual nitrogen intake and total annual nitrogen retention of the animal and the new guidelines provide equations for calculating both nitrogen intake and retention.
The methodology for estimating indirect $N_2O$ emissions from manure management was also included. Tier 1 involves estimating emissions from volatilized nitrogen in forms of ammonia ($NH_3$) and nitrogen oxides ($NO_x$) from manure management systems. It is based on multiplication of the amount of nitrogen excreted (from all livestock categories) and managed in each manure management system by a fraction of volatilised nitrogen (default fractions of nitrogen losses from manure management systems due to volatilisation are available in the 2006 IPCC Guidelines). Tier 2 includes the use of country-specific data for some or all of variables described in Tier 1 method. Moreover, an equation to estimate nitrogen losses from leaching and runoff from manure management has been added. As reported in the 2006 IPCC Guidelines, this equation should only be used when country-specific information on the fraction of nitrogen loss due to leaching and runoff from manure management systems is available.
The 2006 IPCC Guidelines have been clearly defined Tier 2 and Tier 3 methods for manure management, noting that while country-specific information on the nitrogen losses from leaching and runoff from manure management are an essential component for such methods, there are currently extremely limited measurement data on leaching and runoff losses from various manure management systems. Accordingly, this could represent a challenge for countries for which $N_2O$ emissions from manure management are key categories.
On coordination with agricultural soils emission category, an equation for calculating the amount of managed manure nitrogen available for application to managed soils or for feed, fuel, or construction purposes was included in the 2006 IPCC Guidelines. This equation considers the annual amount of nitrogen excreted, all nitrogen losses occurred before the spreading of manure on soils and the nitrogen input from bedding for solid storage and deep bedding systems.
Some of the changes described had already been included in the IPCC GPG.

**Box 3.5** – *Warnings on some parameters used to estimate emissions in Manure Management*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Warnings on some parameters used to estimate emissions in Manure Management**

The VS parameter calculated using Equation 10.24 to estimate the volatile solid excretion rates, does not include the VS contribution of bedding added in animal housing. However, it is noted in the 2006 IPCC Guidelines that the contribution of bedding should not be significant. Also, in Equation 10.24, the ash parameter incorrectly refers to the manure, instead of the feed. This inaccuracy has been corrected in the 2019 Refinement.
It is also worth noting that there is little information in the 2006 IPCC Guidelines on estimating methane emissions from anaerobic digesters; however, this lack has been filled in the 2019 Refinement.
When national emissions of $NH_3$ and $NO_x$ from manure management are available, these data should be used instead of the default values reported in the 2006 IPCC Guidelines. For example, in Equation 10.26 $Frac_{GasMS}$ represents the annual amount of $NH_3$ and $NO_x$ emissions from animal housing and manure storage.
In equation 10.34, with respect to the $N_{beddingMS}$ parameter, representing the amount of nitrogen from bedding, it is always necessary to verify the national annual amount of crop residues available for bedding use. This verification is necessary both if default values are used and for country specific values. In general, a verification of the annual amount of crop residues produced, as separated by type of use is necessary to ensure transparency in estimating emissions from the agricultural soils (3.D), field burning of agricultural residues (3.F) and open burning of waste (5.C.2) emission categories. The uses that must be considered are therefore: the amount of agricultural residues used as bedding material; the amount of residues burned on the field; the amount removed from the field and burned under uncontrolled conditions (open burning); the amount of residues left on the field and incorporated into the soil.

**Box 3.6** – *Improvements for manure management in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Improvements for manure management in the 2019 Refinement**

In the 2019 Refinement, emission factors and other parameters for livestock and manure management have been updated. In particular, the following changes are worth noting among others:

- For $CH_4$ emissions, a new and more complex Tier 1 calculation method for methane emissions from manure management is provided, as well as a disaggregation of some Tier 1 and Tier 2 parameters according to the productivity level and a revised Tier 2 methane conversion factors for manure management.
- For direct $N_2O$ emissions, Tier 1 nitrogen excretion values were revised and a Tier 2 method for swine and poultry was introduced.
- For indirect $N_2O$ emissions, a new Tier 1 method for estimating N lost through leaching was added, and guidance on coordination with soils emissions was updated.

## 3.5 Rice cultivation (3.C)

### *3.5.1 Overarching changes*

The 2006 IPCC Guidelines introduced several changes for rice cultivation: revision of emission and scaling factors derived from updated analysis of available data; use of daily, instead of seasonal, emission factors to allow more flexibility in separating cropping seasons and fallow periods; provision of new scaling factors to account for differences in water regime in the preseason before cultivation ($SF_p$), to consider the type and amount of organic amendment applied ($SF_o$) and to include the differences due to the soil and rice cultivar ($SF_{s,r}$); introduction of information about the Tier 3 approach. Some of the changes described had already been included in the IPCC GPG.

**Box 3.7** – *Improvements for rice cultivation in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Improvements for rice cultivation in the 2019 Refinement**

In the 2019 Refinement, the following improvements were made for rice cultivation:

- provision of new baseline EFs stratified by region and update of the world emission factor;
- update of scaling factors for water regimes before (only for disaggregated case and with a new water regime) and during the cultivation period;
- update of default conversion factors for different types of organic amendments;
- introduction of new default cultivation periods;
- added a Box 5.2a provides information about measuring methane emissions for developing a baseline emission factor for rice cultivation for Tier 2 method;
- added examples.

## 3.6 Agricultural soils (3.D)

### *3.6.1 Overarching changes*

In the following sections, changes in the 2006 IPCC Guidelines compared to the 1996 IPCC Guidelines are described separately for direct and indirect $N_2O$ emissions.

### *3.6.2 Direct $N_2O$ emissions from managed soils (3.D.a)*

The 2006 IPCC Guidelines broadened the scope of the direct $N_2O$ emissions estimations by including guidance on direct $N_2O$ emissions from all managed land in one place, by broadening the subcategories for organic nitrogen inputs applied as fertilizer (including animal manure, compost, sewage sludge, other organic amendments used as fertiliser is now considered) and by including nitrogen (N) inputs from urine and dung from grazing animals (pasture, rage and paddock - previously part of $N_2O$ emissions from Manure Management). N mineralisation associated with loss of soil organic matter resulting from change of land use or management on mineral soils is also considered a source.

**Box 3.8** – *Warnings on some parameters used to estimate emissions in Agricultural Soils*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Warnings on some parameters used to estimate emissions in Agricultural Soils**

The 2006 IPCC Guidelines assume that where soil C is lost through oxidation as a result of land-use or management change, this loss will be accompanied by a simultaneous mineralisation of N. Where a loss of soil C occurs, this mineralised N is regarded as an additional source of N available for conversion to $N_2O$. The opposite process to mineralisation, whereby inorganic N is sequestered into newly formed SOM (soil organic matter), is not taken into account in the calculation of the mineralisation N source. This is because of the different dynamics of SOM decomposition and formation, and also because reduced tillage in some circumstances can increase both SOM and $N_2O$ emissions. Countries that base $N_2O$ estimation from soils on complete N balances for soils may face problems with this selective inclusion of emissions.

To calculate the annual amount of N in mineral soils that is mineralized, in association with loss of soil C from soil organic matter as a result of changes to land use or management, coordination with the LULUCF expert is desirable. Only emissions from mineralized nitrogen for the cropland remaining cropland land use category should be reported in direct $N_2O$ emissions from managed soils in agriculture sector.

The amount of nitrogen in synthetic and organic fertilizers is no longer adjusted to account for the amount that volatilises as $NH_3$ and $NO_x$ during spreading.

As regards the annual amount of animal manure N applied to soils, care must be taken to subtract all nitrogen losses occurring in manure management systems, as indicated in Equation 10.34 ($Frac_{LossMS}$ parameter).

For the annual amount of N in crop residues, a verification of the annual amount of crop residues produced separated by type of use is necessary to ensure transparency in estimating emissions from the agricultural soils (3.D), field burning of agricultural residues (3.F) and open burning of waste (5.C.2) emission categories, as already reported in the Box 5.

Coordination with the LULUCF expert is necessary for the collection of data on organic soils and agricultural areas and production to ensure consistency of emission estimates between emission categories of different sectors. Similarly, coordination with the waste expert needs to be activated for sewage sludge data.

Direct $N_2O$ emissions from biological N fixation are no longer included in 2006 IPCC Guidelines because of the lack of evidence of significant emissions arising from the fixation process itself.

A detailed methodology had been developed for estimating N already in GPG. In addition, in the 2006 IPCC Guidelines the nitrogen residue from perennial forage crops is only accounted for during periodic pasture renewal, i.e. not necessarily on an annual basis as is the case with annual crops.

Moreover, several changes occurred in the 2006 IPCC Guidelines for emission factors for $N_2O$ emissions from soils (the new list of EFs is provided in Table 11.1[6]), which were generally revised and accompanied by uncertainty ranges:

- **$EF_1$** for N additions due to mineral fertilisers, organic amendments, crop residues and N mineralization due to loss of soil C was revised to 0.01 compared to the 0.0125 value from the 1996 IPCC Guidelines and GPG. Moreover, $EF_1$ for flooded rice fields was added.
- **$EF_2$** values for organic soils have been split between "crop and grassland soils" and "forest soils" and by climate zone (temperate/boreal and tropical).
- **$EF_3$** values for the amount of $N_2O$ emitted from urine and dung N deposited by grazing animals on pasture, range and paddock (cattle, poultry and pigs) are introduced as a new element, as well as ones for "sheep and other animals".

**Box 3.9** – *Improvements for direct $N_2O$ emissions in agricultural soils in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Improvements for direct $N_2O$ emissions in agricultural soils in the 2019 Refinement**

In the 2019 Refinement, the following improvements concerned direct $N_2O$ emissions from agricultural soils:

- EFs were disaggregated into values for synthetic and organic fertilisers (decrease for organic), and for synthetic fertilisers by climate type (increase for wet, decrease for dry);
- EFs for flooding rice were updated and new values by water regimes are available;
- EFs for grazing were updated and new values by climatic zone are available;
- Guidance for Tier 1 histosols cultivation was updated, referring to the 2013 wetlands supplement, with disaggregated EFs for more detailed categories of cropland and grassland;
- Crop residues calculation method was updated.

[6] 2006 IPCC Guidelines, Volume 4, Chapter 11, "$N_2O$ emissions from managed soils, and $CO_2$ emissions from lime and urea application"

### *3.6.3 Indirect $N_2O$ emissions from managed soils (3.D.b)*

The indirect $N_2O$ emission from managed soils arising from agricultural inputs of N have been amended by some new sources of indirect N, such as "N in crop residues" (above and below ground), "N inputs from urine and dung N deposited on pasture, rage and paddock" and "N mineralisation associated with loss of soil organic matter due to land-use change or management on mineral soils". Also, "N from sewage sludge applied to soils" and "$N_2O$ emissions from discharge of sewage" are now included in "organic N applied as fertilizer" (including animal manure, compost, sewage sludge, rendering waste). The sources of indirect $N_2O$ emissions generally follow the sources for direct $N_2O$ emissions from soils.

In the 2006 IPCC Guidelines, the overall value for the emission factor for leached N ($EF_5$) has been changed from 0.025 to 0.0075 kg $N_2O$–N/kg N leaching/runoff.

**Box 3.10** – *Improvements for indirect $N_2O$ emissions in agricultural soils in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Improvements for indirect $N_2O$ emissions in agricultural soils in the 2019 Refinement**

In the 2019 Refinement, the following improvements concerned indirect $N_2O$ emissions from agricultural soils:

- EF for volatilization and redeposition disaggregated by climate type were revised;
- the volatilisation fraction by type of synthetic fertilizer was updated, with a 15-fold difference in value between the highest (urea) and lowest (nitrate-based) types.

## 3.7 Prescribed burning of savannas (3.E)

### *3.7.1 Overarching changes*

The 2006 IPCC Guidelines provide a generic approach for estimating emissions from fires, which includes emissions from prescribed burning of savannas. A generic methodology to estimate emissions for any type of fire considering different vegetation types is reported in Equation 2.27 of Chapter 2 of Volume 4.

Although the methodology does not differ much from the 1996 IPCC Guidelines, it has new elements such as the possibility of estimating emissions of various types of savanna (not only tropical).

The emission factors for CO, $CH_4$, $N_2O$ and $NO_x$ have also been modified.

**Box 3.11** – *Improvements for prescribed burning of savannas in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Improvements for prescribed burning of savannas in the 2019 Refinement**

As reported in the 2006 IPCC Guidelines, in the 2019 Refinement prescribed burning of savannas is included under the grassland biomass burning section (Chapter 6, Grassland, Section 6.3.4). Note to avoid double counting as one type of savanna vegetation is similar to that of Forest Land.

## 3.8 Field burning of agricultural residues (3.F)

### *3.8.1 Overarching changes*

The 2006 IPCC Guidelines provide a generic approach for estimating emissions from fires, which includes emissions from field burning of agricultural residues. A generic methodology to estimate emissions is reported in Equation 2.27 of Chapter 2, Volume 4. The methodology does not differ much from the 1996 IPCC Guidelines, however the emission factors for CO, $CH_4$, $N_2O$ and $NO_x$ have been modified.

**Box 3.12** – *Practical requirements for data collection for Field Burning of Agricultural Residues*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Practical requirements for data collection for Field Burning of Agricultural Residues**

A verification of the annual amount of crop residues produced separated by type of use is necessary to ensure transparency in estimating emissions from the agricultural soils (3.D), field burning of agricultural residues (3.F) and open burning of waste (5.C.2) emission categories, as already reported in Box 5 and Box 8.

To calculate the annual amount of biomass from agricultural residues used for heating, whose emissions should not be reported in category 3.F, coordination with the energy expert is desirable.

**Box 3.13** – *Improvements for field burning of agricultural residues in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Improvements for field burning of agricultural residues in the 2019 Refinement**

In the 2019 Refinement, the method for estimating mass of fuel in croplands that is consistent with the method for estimating soil $N_2O$ emissions from crop residues in agricultural soils (i.e., mass of residues) has been refined.

## 3.9 Liming (3.G)

### *3.9.1 Overarching changes*

In the 2006 IPCC Guidelines, Equation 11.12 (already reported in the LULUCF GPG) is used to estimate $CO_2$ emissions from liming.

**Box 3.14** – *Practical requirements for data collection for Liming*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Practical requirements for data collection for Liming**

If only data for the total amount of carbonate containing lime applied annually to soils without differentiating between the total amount of limestone and dolomite is available, the inventory expert can contact the largest lime producer(s) in the country to try to estimate the missing information. In fact, the IPCC Guidelines contain two emission factors, one for limestone and one for dolomite.

It is also worth noting that neither the emission factors nor the methodology for this category have been reviewed in the 2019 Refinement.

## 3.10 Urea application (3.H)

### *3.10.1 Overarching changes*

The 2006 IPCC Guidelines included a new source category for urea application, to include the process of adding urea to soils during fertilisation which leads to a loss of $CO_2$ that was fixed in the industrial production process, since the $CO_2$ removal from the atmosphere during urea manufacturing is estimated in the Industrial Processes and Product Use Sector (IPPU Sector).

**Box 3.15** – *Practical requirements for data collection for Urea Application*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Practical requirements for data collection for Urea Application**

To verify the completeness of the inventory, checks on urea data will be made between apparent consumption and end uses, based on production, import, export and final uses data collected from domestic producers, trade associations, or statistical sources.

Neither the emission factors nor the methodology have been reviewed in the 2019 Refinement.

## 3.11 Other carbon-containing fertilizers (3.I)

### *3.11.1 Overarching changes*

In the IPCC Guidelines, there is no methodology for estimating $CO_2$ from other carbon-containing fertilizers, that is a non-mandatory category.

**Box 3.16** – *Practical requirements for data collection and for estimation process for Other Carbon-containing Fertilizers*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Practical requirements for data collection and for estimation process for Other Carbon-containing Fertilizers**

Emissions can be estimated by referring to the methodology for estimating emissions from liming (e.g. considering the use of fertilizer as activity data and the emission factor based on carbon content). The emission category includes, for example, emissions from the soil application of the calcium ammonium nitrate (CAN). This product contains only ammonium nitrate and limestone or dolomite, with a N-content basically equal to 27%. Based on the molecular weight of nitrogen and ammonium nitrate and the percentage of N-content in the product, the amount of limestone/dolomite contained in the product can be estimated. Using the average emission factor from liming, the $CO_2$ emissions can be estimated.

# SECTION II – LULUCF

## Overview

The 2006 IPCC Guidelines significantly modify the approaches previously used in the 1996 IPCC Guidelines for the estimation of the GHG emissions and removals related to the LULUCF sector, building on the guidance provided in the 2003 IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (GPG-LULUCF). The key changes are:

- the adoption of the six land use categories, used in the GPG-LULUCG, further sub-divided into land remaining in the same category and land converted from one category to another (categorization of the broad processes of human interaction with the terrestrial environment;
- while the 1996 IPCC GLs mainly dealt with biomass and soil carbon stocks, the 2006 IPCC GLs clearly specify that, for each land category, C stock changes and emission/removal estimation can involve the five carbon pools, i.e. aboveground (living) biomass, belowground (living) biomass, dead wood, litter and soil organic matter -SOM (or soil organic carbon - SOC) as defined in the following table (Table 1.1, IPCC 2006, Vol. 4, Ch.1):

**Table 3.4** – *Definitions for carbon pools used in AFOLU for each land-use category (2006 IPCC Guidelines, Volume 4: Agriculture, Forestry and Other Land Use – Table 1.1)*

| POOL | | DESCRIPTION |
|---|---|---|
| **Biomass** | Above-ground biomass | All biomass of living vegetation, both woody and herbaceous, above the soil including stems, stumps, branches, bark, seeds, and foliage. Note: In cases where forest understory is a relatively small component of the above-ground biomass carbon pool, it is acceptable for the methodologies and associated data used in some tiers to exclude it, provided the tiers are used in a consistent manner throughout the inventory time series. |
| | Below-ground biomass | All biomass of live roots. Fine roots of less than (suggested) 2mm diameter are often excluded because these often cannot be distinguished empirically from soil organic matter or litter. |
| **Dead organic matter** | Dead wood | Includes all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps, larger than or equal to 10 cm in diameter (or the diameter specified by the country). |
| | Litter | Includes all non-living biomass with a size greater than the limit for soil organic matter (suggested 2 mm) and less than the minimum diameter chosen for dead wood (e.g. 10 cm), lying dead, in various states of decomposition above or within the mineral or organic soil. This includes the litter layer as usually defined in soil typologies. Live fine roots above the mineral or organic soil (of less than the minimum diameter limit chosen for below-ground biomass) are included in litter where they cannot be distinguished from it empirically. |
| **Soils** | Soil organic matter[1] | Includes organic carbon in mineral soils to a specified depth chosen by the country and applied consistently through the time series[2]. Live and dead fine roots and DOM within the soil, that are less than the minimum diameter limit (suggested 2 mm) for roots and DOM, are included with soil organic matter where they cannot be distinguished from it empirically. The default for soil depth is 30 cm and guidance on determining country-specific depths is given in Chapter 2.3.3.1. |

[1] Includes organic material (living and non-living) within the soil matrix, operationally defined as a specific size fraction (e.g., all matter passing through a 2 mm sieve). Soil C stock estimates may also include soil inorganic C if using a Tier 3 method. CO2 emissions from liming and urea applications to soils are estimated as fluxes using Tier 1 or Tier 2 method.
[2] Carbon stocks in organic soils are not explicitly computed using Tier 1 or Tier 2 method, (which estimate only annual C flux from organic soils), but C stocks in organic soils can be estimated in a Tier 3 method. Definition of organic soils for classification purposes is provided in Chapter 3.

Considering the first key change, 1996 IPCC Guidelines focused only on a few important processes related to land-use change:

- changes in forest and other woody biomass stocks which include the biomass of existing (i.e. natural) forests, plantations and non-forest trees (e.g. urban and village trees);
- forest and grassland conversion into pasture, cropland and other managed uses;
- abandonment of croplands, pastures, plantations forests, or other managed lands which regrow into their prior natural conditions (grassland or forest);

- changes in soil carbon.

The 2006 IPCC Guidelines, instead, adopt a broader representation of managed lands (detail on this topic are included in section **Errore. L'origine riferimento non è stata trovata.**), designed to allow the inclusion of all managed land area within a country, where human-induced effects occur for production, ecological or social functions. According to IPCC (2010)[7], the managed land is the best available proxy to be used to estimate anthropogenic emissions and removals related to LULUCF for national emission/removal reporting under UNFCCC. Emissions/removals from unmanaged land do not need to be reported. The managed land area can increase across time because of some unmanaged land becomes managed. However, unmanaged land cannot increase and the total area of the land representation must be constant (to ensure consistency); which means that in case of a change in the national total area the entire time series is to be recalculated. The 2006 IPCC Guidelines consider a set of land use categories (Forest Land, Cropland, Grassland, Wetlands, Settlements and Other Land) that are further subdivided into subcategories of land remaining in that land category (e.g. Forest Land remaining Forest Land) and lands converted into that land category (e.g. land converted to Forest Land). For example, in the specific case of Forest Land category, it should include the emissions/removals related to Forest Land remaining Forest Land and the sum of all the emissions/removals related other categories converted into Forest Land (i.e. Cropland to Forest Land, Grassland to Forest Land, Wetlands to Forest Land, Settlements to Forest Land and Other Land to Forest Land).
The 2006 IPCC GLs Harvested Wood Products (HWP) provides three different approaches to estimate Harvested Wood Products (HWP) $CO_2$ emissions and removals. Specific information on this topic are summarised in section **Errore. L'origine riferimento non è stata trovata.** of this report and in the 2006 IPCC GLs at Vol. 4, Ch.12 (IPCC, 2006). Linkages between 1996 IPCC land-use processes classification and LULUCF categories, as described in the 2006 Guidelines, are clearly outlined in sections from 3.1.2.1 to 3.1.2.4 of the Good Practice Guidance for LULUCF (IPCC, 2003)[8].

**Box 3.17** – *Challenges in the LULUCF sector*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Challenges in the LULUCF sector**

Consistent land representation is the key step for the assessment of GHG emissions and $CO_2$ removals for LULUCF sector. The land representation needs to be complete:
- total land area of country has to be represented;
- managed and unmanaged land has to be reported.

Each land use category should be detailed at the national level, in line with IPCC definition (IPCC 2006, vol. 4 ch.1, table 1), described in a transparent manner; each land use category definition should be applied consistently over time.
It is a good practice to track over time the area of unmanaged land included in the country, as it could be converted into managed land in the future. If it occurs, it will be included in the managed land surface in the following national inventory submissions. This means that, for example, if a land surface become managed in 2011, this land area is to be reported as managed from the year 2011 onward only.

**Box 3.18** – *The impact of the 2019 Refinement on LULUCF categories*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**The impact of the 2019 Refinement on LULUCF categories**

The 2019 Refinement affects most LULUCF categories, by the inclusion of updated default emission factors and methods, for the different carbon pools. The impact on LULUCF emissions and removals is though highly dependent on the country specific circumstances, accordingly it is difficult to quantify it without detailed information on country-specific circumstances (e.g., spatial explicit maps of the distribution of tree species, distribution of tree species in agroforestry systems and soil conditions). Specific changes are highlighted under the specific categories in the next chapters.

[7] IPCC [Intergovernmental Panel on Climate Change], 2010. Revisiting the use of managed Land as a proxy for estimating national anthropogenic emissions and removals. In: Eggleston, H.S., Srivastava, N., Tanabe, K., Baasansuren, J. (Eds.), Meeting Report, 5 -7 May, 2009, INPE, S˜ao Jos´e Dos Campos, Brazil, Pub. IGES, Japan 2010.
[8] IPCC [Intergovernmental Panel on Climate Change], 2003. Good Practice Guidance for Land Use, Land-Use Change and Forestry, Japan.

## 3.12 Tabular summary of changes for LULUCF categories

**Table 3.5 –** LULUCF categories: tabular summary of changes from the revised 1996 IPCC Guidelines to the 2006 IPCC Guidelines *(highlighted in red are new categories/subcategories, in grey the 1996 categories, removed by the 2006 IPCC Guidelines).*

| 1996 IPCC Guidelines | 2006 IPCC Guidelines |
|---|---|
| | |
| **Changes in wood biomass stocks** | **Forest Land*** |
| **Forest and grassland conversions** | **Grassland*** |
| **Abandonment of Managed Lands** | **Cropland*** |
| **Changes in Soil Carbon** | **Settlements*** |
| | **Wetlands*** |
| | **Other Land*** |
| | **Harvested Wood Products (HWP)*** |
| | **Other*** |

**These categories are the same categories already included in the LULUCF sector by the 2003 IPCC Good Practice Guidance for LULUCF, excepting the categories Liming and Urea application, moved in the Agriculture sector-*

## 3.13 2006 IPCC categories in the CRTs

**Table 3.6** – *LULUCF reporting codes in the CRTs*

| **LULUCF** |
|---|
| **4.A Forest Land** |
| 4.A.1 Forest Land Remaining Forest Land |
| 4.A.2 Land Converted to Forest Land |
| 4.A.2.a Cropland Converted to Forest Land |
| 4.A.2.b Grassland Converted to Forest Land |
| 4.A.2.c Wetlands Converted to Forest Land |
| 4.A.2.d Settlements Converted to Forest Land |
| 4.A.2.e Other Land Converted to Forest Land |
| **4.B Cropland** |
| 4.B.1 Cropland Remaining Cropland |
| 4.B.2 Land Converted to Cropland |
| 4.B.2.a Forest Land Converted to Cropland |
| 4.B.2.b Grassland Converted to Cropland |
| 4.B.2.c Wetlands Converted to Cropland |
| 4.B.2.d Settlements Converted to Cropland |
| 4.B.2.e Other Land Converted to Cropland |
| **4.C Grassland** |
| 4.C.1 Grassland Remaining Grassland |
| 4.C.2 Land Converted to Grassland |
| 4.C.2.a Forest Land Converted to Grassland |
| 4.C.2.b Cropland Converted to Grassland |
| 4.C.2.c Wetlands Converted to Grassland |
| 4.C.2.d Settlements Converted to Grassland |
| 4.C.2.e Other Land Converted to Grassland |
| **4.D Wetlands** |
| 4.D.1 Wetlands Remaining Wetlands |
| 4.D.1.a Peat Extraction Remaining Peat Extraction |
| 4.D.1.b Flooded Land Remaining Flooded Land |
| 4.D.1.c Other wetlands remaining other wetlands |

| LULUCF |
|---|
| 4.D.2 Land Converted to Wetlands |
| 4.D.2.a Land Converted for Peat Extraction |
| 4.D.2.b Land Converted to Flooded Land |
| 4.D.2.c Land Converted to Other Wetlands |
| **4.E Settlements** |
| 4.E.1 Settlements Remaining Settlements |
| 4.E.2 Land Converted to Settlements |
| 4.E.2.a Forest Land Converted to Settlements |
| 4.E.2.b Cropland Converted to Settlements |
| 4.E.2.c Grassland Converted to Settlements |
| 4.E.2.d Wetlands Converted to Settlements |
| 4.E.2.e Other Land Converted to Settlements |
| **4.F Total Other Land** |
| 4.F.1 Other Land Remaining Other Land |
| 4.F.2 Land Converted to Other Land |
| 4.F.2.a Forest Land Converted to Other Land |
| 4.F.2.b Cropland Converted to Other Land |
| 4.F.2.c Grassland Converted to Other Land |
| 4.F.2.d Wetlands Converted to Other Land |
| 4.F.2.e Settlements Converted to Other Land |
| **4.G Total Harvested Wood Products (HWP)** |
| 4.G.1. Solid wood [(7)] |
| 4.G.2. Paper and paperboard |
| 4.G.3. Other *(child nodes can be added)* |
| **4.H Other *(child nodes can be added)*** |

## 3.14 Generic methodologies applicable to multiple land use categories

### *3.14.1 Overarching changes*

The 2006 IPCC Guidelines provides a dedicated chapter to describe generic methodologies for estimating ecosystem carbon stock changes as well as for estimating non-$CO_2$ emissions from fire, that can be applied for any of the six land-use categories. The chapter set out a general framework for applying the methods to each of the la land-use category, providing a general guidance on higher Tier methods and on uncertainty estimation.

### *3.14.2 Carbon stock change estimation*

The 2006 Guidelines provides information to estimate annual C stock changes for each carbon pool (*aboveground and belowground biomass, deadwood, litter, soil*), in all land-use categories. For each land-use category, stratification, or subdivision of land area (e.g., climate zone, ecotype, soil type, management regime etc.) has to be applied, estimating the carbon stock changes accordingly. Further, carbon stock changes in soil may be disaggregated as to changes in C stocks in *mineral soils* and emissions from *organic soils*.

Two different approaches are provided to estimate carbon stock changes:

- *Gain-loss* method (eq. 2.4, vol. 4, ch.2), a process-based approach, which estimates the net balance of additions to and removals from a carbon stock;
- *Stock-difference* method (eq. 2.4, vol. 4, ch.2), which estimates the difference in carbon stocks at two points in time.

For inventory purposes, changes in C stock are estimated for (i) land remaining in the same land-use category and (ii) land converted to a new land-use category. The reporting convention is that all emissions and removals associated with a land-use change are reported in the new land-use category.

The length of time that land remains in a conversion category after a change in land use is by default 20 years; other transition periods can be used at higher Tiers according to national circumstances.

## Land remaining in a land-use category

***Biomass***

*Gain-loss* or *stock-difference* methods can be applied to estimate biomass C stock changes; different tiers can be used, according to the data and resource availability, at country level.

Gain-loss method (eq. 2.4, 2.7, 2.9, 2.10, 2.11, 2.12, 2.13, 2.14, vol. 4, ch.2), can be adopted by countries that do not have national inventory systems designed for estimating woody biomass stocks. Default data are provided in each land-use category chapter, to allow a Tier 1 estimation of biomass carbon stock changes in case of missing country-specific data.

The stock-difference method (eq. 2.8, vol. 4, ch.2), requires biomass carbon stock inventories for a given land area, at two points in time; therefore, its applications is suitable in countries having national forest inventory systems and other land-use categories, where the stocks of different biomass pools are measured at periodic intervals.

***Dead organic matter***

Dead organic matter (DOM) comprises dead wood and litter.

***Tier 1***

It is assumed that, for both dead wood and litter pools for all land-use categories, their stocks are not changing over time if the land remains within the same land-use category; therefore countries adopting Tier 1 method to estimate DOM pools can report zero carbon stock changes in land remaining in the same land-use category. Consequently, $CO_2$ emissions resulting from the combustion of dead organic matter during fire are not reported, nor are the increases in dead organic matter carbon stocks in the years following fire. However, emissions of non-$CO_2$ gases from burning of DOM pools are reported.

***Tier 2 and 3***

DOM carbon stock changes can be estimated with equation 2.17 (vol. 4, ch.2), by applying the two above-mentioned methods, taking into account inputs and outputs (gain-loss method, equation 2.18) or estimating the DOM C pools at two points in time (stock-difference method, equation 2.19). A higher knowledge of carbon dynamics (estimates of transfer and decay rates) and data availability (harvesting and disturbances and their impacts on DOM pool dynamics) is required to apply Tier 2 and Tier 3 approaches. Also, for DOM pools, the methodological choose depends on the available data and will likely be in line with the method chosen for biomass carbon stocks. The estimation of biomass carbon transferred to dead organic matter pools is estimated using the equations 2.20, 2.21, 2.22 (vol. 4, ch.2).

***Soil***

The land use and management affect soil organic carbon differently in mineral soils, directly influenced by land-use and management activities, and in organic soils. The annual change in carbons stocks in soils includes estimates of soil organic carbon (SOC) stock changes for mineral soils and $CO_2$ emissions form organic soils, due to enhanced microbial decomposition caused by drainage and associated management activity.

Equation 2.24 (vol. 4, ch.2) has to be used to estimate the total change in soil C stocks, including changes in carbon stock in mineral soils, the carbon loss from drained organic soils and the change in inorganic soil carbon stock, assumed to be zero unless using Tier 3 approach.

A default depth of 30 cm is considered under Tier 1.

***Tier 1***

- *Mineral soils*

The default method, using the equation 2.25 (vol. 4, ch. 2) is based on the changes in soil C stocks over a finite period of time, driven by a management change that affect the SOC in a in a reference condition (i.e., native vegetation that is not degraded or improved). This basic concept underlines that:

- under a given set of climate and management conditions soils tend towards an equilibrium carbon content;
- soil organic C stock changes during the transition to a new equilibrium SOC occurs in a linear fashion.

For each inventory time period, the SOC stocks are estimated for the first ($SOC_{0\text{-}T}$) and last year ($SOC_0$) based on multiplying the reference C stocks ($SOC_{REF}$) by stock change factors (i.e. $F_{LU}$ = for land-use systems, $F_{MG}$ = for management regime, $F_I$ = for input of organic matter). Annual rates of carbon stock change are estimated as the difference in stocks at two points in time divided by the time dependence of the stock change factors.

Default reference soil C stocks for mineral soils, considering a default depth of 30 cm, are provided in the table 2.3 (vol. 4, ch.2). A default transition period of 20 years is considered.

- *Organic soils*

The annual carbon loss from drained organic soils can be estimated with equation 2.26 (vol. 4, ch.2), considering the land area of drained organic soils and the emission factor for climate type.

***Tier 2***

- *Mineral soils*

Country specific data can be used to improve the assessment of the elements of the equation 2.25 (vol. 4, ch.2); in particular country specific stock change factors and/or reference C stocks, as well as the enhancement of the stratification (i.e. management systems, climate, or soil categories).

- *Organic soils*

The Tier 2 approach considers the use of country specific information in application of equation 2.26 (vol. 4, ch.2), as well as the enhancement of the stratification for climate and management systems.

***Tier 3***

It involves the use of more advanced models than Tiers 1 and 2 methods, and/or by developing a measurement-based inventory with a monitoring network. For mineral soils, Tier 3 modelling approaches can address the influence of land use and management changes on carbon dynamic, considering the carbon transfers between biomass, DOM and soils, usually providing a more accurate estimation of carbon stock changes.

## Land converted to a new land-use category

***Biomass***

Annual carbon stock changes in aboveground and belowground biomass, on land converted to a new land-use category can be estimated with *gain-loss* method (eq. 2.4, vol. 4, ch.2), estimating the annual carbon gain and loss separately for each land use (e.g., Forest Land, Cropland, Grassland), management category (e.g., e.g., natural forest, plantation), and specific strata (e.g., climate or forest type).

***Tier 1***

The annual increase in biomass carbon stock due to land converted to another land-use category can be estimated with the abovementioned equation 2.9 (vol. 4, ch.2), based on the Tier 1 default assumption that there is no change in initial biomass carbon stocks due to conversion, to be applied if the data on previous land uses are not available (see Approach 1 or 2 described in the section 12). If the previous land use on a converted area is known, then the Tier 2 method described below can be used.

The annual decrease in biomass carbon stock due to losses on converted land (wood removals, and disturbances) can be estimated with the abovementioned equations 2.11 to 2.14 (vol. 4, ch.2), based on the Tier 1 default assumption that there is no change in initial carbon stocks in biomass. It can be applied for areas estimated with the use of Approach 1 or 2, as described in the section 12.

***Tier 2 and 3***

Country specific data and process models are usually adopted under higher Tiers, allowing a more accurate estimates of carbon stocks changes in biomass. For Tier 2, equation 2.15 (vol. 4, ch.2) can be used, assessing the carbon stock changes as the sum of increase in carbon stock due to biomass growth, changes due to actual conversion (difference between biomass stocks before and after conversion), and decrease in carbon stocks due to losses. Equation 2.16 (vol. 4, ch.2) should be used to calculate the initial changes in carbon stocks in biomass.

***Dead organic matter***

***Tier 1***

DOM pools in non-forest categories after conversion is assumed to be zero, therefore assumed to contain no carbon. For forest land converted to another land-use category is assumed that all DOM carbon losses occur in the year of land-use conversion. Conversely, land conversion to forest land results in increase of litter and dead wood carbon pools, starting from zero, over a transition period (default assumption is 20 years). Longer transition periods may be adopted by countries that use higher Tier methods. Using Tier 1 method, in a land conversion, the biomass carbon is considered totally released to the atmosphere (i.e. zero carbon is transferred to the DOM pools). Tier 1 default values for litter and dead wood carbon stock are provided in the table 2.2 (vol. 4, ch. 2).

***Tier 2 and 3***

Non-zero estimates of litter and dead wood pools in the appropriate land-use categories or subcategories can be assumed using higher Tier methods (e.g. settlements or grassland can contain some litter and dead wood pools that can be estimated as input or output associated with the land-use change). Equation 2.23 (vol. 4, ch. 2) should be used to calculate the estimating changes in carbon stocks in dead wood and litter pools due to land conversion, accounting for the carbon transferred to the dead wood and litter pools and for any carbon released from DOM pools, e.g., during slash burning.

### *3.14.3 Non-$CO_2$ emissions estimation*

Emissions of non-greenhouse gases are released from biomass burning, livestock and manure management, or soils. Guidance on $CH_4$ and $N_2O$ emissions from livestock and manure as well as $N_2O$ emissions from soils are provided in section 2, 3 and 5, of the Agriculture section, respectively.

The 2006 IPCC Guidelines, while fully implementing the GPG for LULUCF in the estimation processes for the sector, provide a generic approach to estimate GHG emissions from fires by addressing the following elements:

- Fire is considered as a disturbance that affects all the carbon pools (not only above ground biomass).
- Annual emissions have to be estimated and reported except where annual $CO_2$ emissions and removals are equivalent (e.g. some grasslands and burning of agricultural residues).
- Emissions by sources ($CO_2$ and non- $CO_2$) and removals by sinks associated with all fires on managed land (both prescribed fires and wildfires) are now estimated and need to be reported

within each managed lands, consistently with the concept of managed land as a proxy for identifying anthropogenic emissions by sources and removals by sinks.
- Fires on unmanaged land should be reported under the new land use category only in case they are followed by a land-use change. Indeed, while all the emissions or removals on managed lands (whether of natural or man-made origin) are usually reported, wildfires and other disturbances on unmanaged land cannot, in general, be associated to an anthropogenic or natural cause. Therefore, no emissions should be reported to natural disturbances on unmanaged land unless the disturbance is followed by a land-use change, in which case the land affected by disturbance is considered to be managed.

The estimation of emissions of individual GHG for any type of fire is based on the equation 2.7 (vol. 4, ch.2), linking the amount of emissions to the fuel available on the burned area. The mass of fuel available for combustion includes biomass, ground litter and dead wood. When Tier 1 methods are used then litter and dead wood pools are assumed zero, except where there is a land-use change. In the Tables 2,4 2.5 and 2.6 (vol. 4, ch.2), the default values for fuel biomass consumption, emission factors for burning types and combustion factor, respectively.
Tier 2 approach uses the same equation 2.7, with the adoption of country-derived emission factors and/or more refined estimates of fuel densities and combustion factors than those provided in the default tables. Tier 3 methods are more comprehensive and include considerations of the dynamics of fuels (biomass and dead organic matter).

**Box 3.19** – *Generic methodologies applicable to multiple land-use categories*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

## C stock change estimation

- Estimation of annual C stock changes in carbon pools is strictly linked to data and model availability. Table 1.2 (IPCC 2006, vol.4, ch.1) is an useful tool to understand the relevance of each pool and land use categories for Tier 1 application; a cross-reference to the specific Guidelines sections are also included, as well as linkages to the 1996 Guidelines;
- In applying the *gain-loss* or *stock-difference* methods, the relevant area is clearly the area of land remaining in the relevant category at the end of the year for which the inventory is being estimated. Any other land will be in a conversion category. Same methods apply to land under conversion;
- Using the *stock-difference* method, the area of land in the 2 points in time, i.e. t1 and t2, is the same to ensure that correct estimation is carried out, avoiding to bias stock change estimates because of area changes between the 2 points in time; it is good practice to use the area at the end of the inventory period (t2) to perform the calculation;
- C stock changes in mineral soils are triggered by land use and/or management changes; if no data is available in relation to changes in management practices, the soil can considered to be in equilibrium. Where data are not available, categories are to be reported as Not Estimated;
- Note that HWP is treated, in the 2006 IPCC Guidelines, as an additional carbon pool, being part of the carbon cycle (IPCC, 2006, vol.4, ch. 2, figure 2.1).

## Non-$CO_2$ emissions estimation

- It is *good practice* to check for complete coverage of $CO_2$ and non-$CO_2$ emissions due to losses in carbon stocks and pools to avoid omissions or double counting;
- lack of activity data related to management practices adopted for grassland and for cropland;
- requirement of country specific conversion coefficients (i.e. default factors to estimates carbon stock changes for woody cropland are actually used);
- need to use remote sensed data to create a consistent informative basis (i.e. assess land areas, reporting the land use categories).

**Box 3.20** – *Improvements of generic methods in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

The 2019 Refinement has introduced several improvements and additional guidance, including the following:

### C stock change estimation

- Use of allometric models for biomass estimation to be used with country specific data to estimate carbon stocks (section 2.3.1.3);
- Use of biomass density maps, constructed from remotely sensed data for biomass estimation *(*section 2.3.1.3*)*, to be used to enhance the stratification of ground inventories, to supply carbon stock changes estimates in under-sampled or inaccessible areas or for verification purposes:
- Updates default values for litter and dead wood carbon stocks (table 2.2) and for soil organic carbon stocks for mineral soils (table 2.3);
- Tier 2 method to estimate the impact of biochar C amendments on mineral soils (eq. 2.25A);
- Generic guidance for Tier 3 methods.

### Non-$CO_2$ emissions estimation

- Updates default values for fuel (dead organic matter and live biomass) biomass consumption (table 2.4), emission factors for various types of burning (table 2.5) and combustion factor for fires in a range of vegetation types (table 2.6).

Additional guidance for Tier 3 methods has been introduced, providing a sound scientific basis for the development of Tier 3 inventories in the AFOLU sector, as

- guidance for measurement-based Tier 3 inventories, from the design of an appropriate statistical sampling to the methods and data needed to estimate GHG emissions, with a focus on disturbance events;
- guidance for model-based Tier 3 inventories, using empirical, process-based, hybrid and/or other types of models;
- guidance on how to parameterize, evaluate, calibrate, and transparently document a Tier 3 method for the AFOLU sector (table 2.6A, table 2.6B).

A specific section (2.6) has been included on interannual variability in the AFOLU sector (i.e. natural disturbances, climate variability and variation in the rate of human activities, including land use), providing guidance to be used by countries that choose to disaggregate their reported Managed Land Proxy (MLP) emissions and removals into those that are considered to result from human activities and those that are considered to result from natural disturbances.

Despite these changes not being yet mandatory for UNFCCC reporting, it is nevertheless suggested to consider their application aiming to produce more accurate estimates, by the using of updates emission factors and methods, and to enhance the overall reporting transparency and completeness.

## 3.15 Consistent representation of land

### *3.15.1 Overarching changes*

Land representation, aimed to represent land-use categories, and conversions between land-use categories, is a key point to achieve an accurate estimate of emission and removal of greenhouse gases of the LULUCF sector. The 2006 IPCC Guidelines provides guidance on the three generic approaches to be used in land classification challenge, on the basis of country available data and the data collection systems.

### *3.15.2 Land-use categories*

The major change, provided by the 2006 IPCC Guidelines, is the definition of six broad land-use categories, i.e. forest land, cropland, grassland, wetlands, settlements, other land. These land-use categories allow a land classification in most countries, accommodating differences in national land-use classification systems, and may be readily stratified (e.g., by climate or ecological zones). National definitions for these categories will be used by countries, providing description of definitions and by applying consistently for national land area over time. In the 2006 IPCC Guidelines, the estimation of emissions and removals occurring on managed land continues to be used as a proxy for anthropogenic emissions and removals (as adopted in the GPG-LULUCF) and does not include emissions and

removals on unmanaged lands[9]; description of methods and definitions used to determine areas of managed and unmanaged lands shall be provided, accordingly. The land-use categories for greenhouse gas inventory reporting are:

***Forest Land***
This category includes all land with woody vegetation consistent with thresholds used to define Forest Land in the national greenhouse gas inventory. It also includes systems with a vegetation structure that currently fall below, but *in situ* could potentially reach the threshold values used by a country to define the Forest Land category.

***Cropland***
This category includes cropped land, including rice fields, and agro-forestry systems where the vegetation structure falls below the thresholds used for the Forest Land category.

***Grassland***
This category includes rangelands and pasture land that are not considered Cropland. It also includes systems with woody vegetation and other non-grass vegetation such as herbs and brushes that fall below the threshold values used in the Forest Land category. The category also includes all grassland from wild lands to recreational areas as well as agricultural and silvi-pastural systems, consistent with national definitions.

***Wetlands***
This category includes areas of peat extraction and land that is covered or saturated by water for all or part of the year (e.g., peatlands) and that does not fall into the Forest Land, Cropland, Grassland or Settlements categories. It includes reservoirs as a managed sub-division and natural rivers and lakes as unmanaged sub-divisions.

***Settlements***
This category includes all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other categories. This should be consistent with national definitions.

***Other Land***
This category includes bare soil, rock, ice, and all land areas that do not fall into any of the other five categories. It allows the total of identified land areas to match the national area, where data are available. If data are available, countries are encouraged to classify unmanaged lands by the above land-use categories (e.g., into Unmanaged Forest Land, Unmanaged Grassland, and Unmanaged Wetlands). This will improve transparency and enhance the ability to track land-use conversions from specific types of unmanaged lands into the categories above.
The land-use categories may be further stratified, by climate, ecological zone, soil, vegetation types, etc. The land-use conversions need to be assessed to estimate the associated carbon stock changes and GHG emissions and removals.

### *3.15.3 Representing land-use areas*
The 2006 IPCC Guidelines describes three approaches may be used to represent areas of land-use for the land-use categories; the approaches are not presented as hierarchical tiers and do not imply any increase or decrease in accuracy, but each country has to select the appropriate approaches, or mix of approaches, considering national circumstances, as national data collection methods.
Inventory requires a consistent time series of land-use categories and land-use changes, ensuring that the areas of managed and unmanaged land are both defined and estimated consistently. In the Annexes 3A.3 and 3A.4 provides general guidance on how collect new data to implement the 2006 IPCC Guidelines, in particular on sampling techniques (Annex 3A.3) and on spatially explicit (Approach 3) datasets (Annex 3A.4).

[9] IPCC [Intergovernmental Panel on Climate Change], 2010. Revisiting the Use of Managed Land as a Proxy for 713 Estimating National Anthropogenic Emissions and Removals, eds: Eggleston H.S., Srivastava N., Tanabe K. and 714 Baasansuren J. Meeting Report, 5 -7 May, 2009, INPE, São José dos Campos, Brazil, Pub. IGES, Japan 2010

***Approach 1***
It represents land-use area totals within a defined spatial unit (such as a country, province or municipality). Only net changes in land-use area can be derived through comparison of data through time. Assessment of area subject to land-use conversion in each category is therefore not carried out.

***Approach 2***
It provides land use changes both from and to a category (i.e. losses or gains in the area of specific land-use categories and what these conversions represent). The approach 2 provides data on land conversion, e.g. forest land converted to cropland, with a spatial resolution. However it has to be to noted that it doesn't track conversions across time (this means that e.g. the forest land converted to cropland is reported for 20 years under the forest land converted to cropland category even in case a further conversion occurs). The final result of this approach can be presented as a non spatially-explicit land-use conversion matrix.

***Approach 3***
It is both spatially and temporally consistent and explicit. Sample-based, survey-based and wall-to-wall methods can be considered Approach 3.
The **three** main **methods** for estimating areas of land-use and land-use change are:
- **sample based methods**: from ground surveys (such as a national forest inventory or national land survey) or remote sensing. Sample-based methods provide an accurate statistical representation of land-use and land-use change but do not provide information on every specific area of the land territory (i.e. is not wall-to-wall spatially explicit);
- **wall-to-wall maps** of land cover and land cover change that, when combined with other data, can be used to generate land-use and land-use change information;
- **statistical survey methods**, to collect information on land-use and land-use change and land management practices; this data is often used in combination with other data to develop a complete land use estimate.

These methods are not mutually exclusive; for example, wall-to-wall methods typically require samples for calibration, validation and uncertainty analysis, and some sample methods require wall-to-wall maps for scaling as well as for dimensioning the sample size and designing the sample grid.

**Box 3.21** – *Consistent representation of land*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Consistent representation of land**

The land representation has to be complete:
- total land area of country has to be represented;
- managed and unmanaged land has to be reported.

It is *good practice* for countries to quantify, and track over time, the area of unmanaged land so that consistency in area accounting is maintained as land-use change occurs.
When the total managed land area increases (by changing from an unmanaged to managed status), particular attention has to be paid to the carbon stock change estimation: carbon stock estimates should be recalculated for the complete inventory time-series area whenever the total area of managed land changes in an annual inventory, to separate carbon stock increases arising from changes in area from true carbon stock changes. This is particular relevant for estimation of soil carbon stock changes, when approach 1 is adopted or when the stock difference method is used.
The starting time for the historical data required is based on the transition period adopted for land use conversion (20 years is recommended as a default).

**Box 3.22** – *Improvements for consistent representation of land in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Improvements for consistent representation of land in the 2019 Refinement**

The 2019 Refinement has introduced several improvements in the consistent representation of land use, as:

- Examples on assigning IPCC land-use and land-use change categories (box 3.1A).
- Examples on how to combine methods and three approaches for representing lands depending on the data availability, providing additional information aimed to an improved use of the country available data collection system (table 3.6A).
- Additional and update information on methods for land-use and land-use change estimation, i.e. wall-to-wall, sample based and survey based methods.
- Guidance on how to combine multiple data sources, detailing good practices to ensure consistency (e.g. spatially and temporally, land conversion areas consistency across the entire time-series), to establish an hierarchy among different data sources, to fill gaps and report uncertainties.
- Derivation of IPCC Land-Use Categories from Land Cover Information.
- Specific section (3.5) on uncertainties associated with the approaches with a focus on the evaluation of land-use and land-use change information generated from remote sensing techniques and estimation of uncertainties.

## 3.16 Forest land (4.A)

### *3.16.1 Overarching changes*

The Forest land chapter in the 2006 IPCC Guidelines, built on the 1996 IPCC Guidelines and GPG-LULUCF, provides methods to:

- Estimate carbon stock changes in the five carbon pools;
- Estimate non-$CO_2$ GHG emissions from biomass burning.

The methods, provided under the three methodological Tiers, should be used together with the generic equations included in the chapter 2 (vol. 4, ch. 2, IPCC 2006) and the approaches to achieve a consistent land representation (vol. 4, ch. 3, IPCC 2006).

### *3.16.2 Forest land remaining in a Forest land*

***Biomass***

All Tiers require information on managed forest land areas, stratified according to forest types, climates, management system and regions.

The *Gain-loss* (eq. 2.7, vol. 4, ch. 2) or the *stock-difference* (eq. 2.8, vol. 4, ch. 2) can be used to estimate the biomass carbon stock changes; while the *Gain-loss* method is applicable for all Tiers, the *stock-difference* method is more suited to higher Tiers, since the stock-difference method requiring the availability of accurate forest related data, usually resulting from periodic national forest inventories.

The 2006 IPCC Guidelines provides the calculation steps for estimating change in carbon stocks in biomass using Tier 1 method; furthermore a specific section has been included to address the uncertainty assessment.

***Tier 1***

Forest area to be used under Tier 1 can be collected through national statistics, survey and international data sources as FAO.

The annual change in carbon stocks in biomass can be estimated using the gain-loss method (eq. 2.7, vol. 4, ch. 2), assessing:

- the annual increase in carbon stock due to biomass growth (eq. 2.9. vol. 4, ch. 2);
- the belowground biomass with a below-ground biomass to above-ground biomass ratio (eq. 2.10, vol. 4, ch. 2); alternatively, biomass conversion and expansion factors ($BCEF_I$) can be used to convert merchantable volume ($m^3$) directly to total biomass using equation 2.10 (vol. 4, ch. 2);
- the annual biomass loss or decrease in biomass carbon stocks (eq. 2.11. vol. 4, ch. 2), estimating the annual carbon loss due to wood removals with eq. 2.12. fuelwood removals (eq. 2.13), disturbances (eq. 2.14); biomass transfer to DOM can be estimated with eq. 2.20, 2.21, 2.22.

The chapter Forest land includes several data and default factors to be used in absence of country specific data:

- above-ground biomass of forest areas affected by disturbances are given in Tables 4.7 and 4.8;
- net average annual above-ground biomass growth values are provided in Tables 4.9, 4.10, and 4.12;
- net volume annual increment values are provided in Tables 4.11A and 4.11B;
- wood density is given in Tables 4.13 and 4.14;
- below-ground biomass to above-ground biomass ratios (R) are given in Table 4.4;
- carbon fraction of dry matter (Table 4.3).

Below-ground carbon stock changes can be assumed to be zero, as a default assumption consistent with the 1996 IPCC Guidelines. Alternatively, default values for below-ground biomass to above-ground biomass ratios (R), provided in Table 4.4, are to be used to estimate below-ground biomass growth.

***Tier 2***

Tier 2 uses country-defined national data sets, with the appropriate resolution to ensure consistent land representation. It may be applied if country specific data and emission/removal factors are available, using equation 2.7 and equation 2.8 to 2.14, also relying on species-specific wood density values provided in tables 4.13 and 4.14). Tables 4.11a and 4.11b provide default values for net annual increment of growing stock. The *stock-difference* method can be used, if the needed country specific data are available.

***Tier 3***
Country specific forest data, usually as resulting from national forest inventories, has to be used for Tier 3, possibly involving use of remotely sensed data allowing for tracking changes in area under different land-use types. It allows for several methods, including process-based models to be transparently documented and validated. Tier 3 requires use of detailed country specific data, resulting from periodic national forest inventories, when the *stock-difference* method is used.

***Dead organic matter***
A decision tree (fig. 2.3, vol.4, ch.2) can help in the selection of the appropriate tier level for the implementation of estimation procedures.
***Tier 1***
It assumes that DOM pools are in equilibrium, and the carbon stock changes in dead wood and litter pools are assumed to be zero.
***Tier 2 and 3***
The *Gain-loss* (eq. 2.18, vol. 4, ch. 2) or the *stock-difference* (eq. 2.19, vol. 4, ch. 2) can be used to estimate the carbon stock changes in the dead wood and litter pools; the forest land area can be further stratified by climate or ecological zones, and classified by forest types, disturbance regime, management practices and, generally, taking into account each factor affecting the DOM dynamics.
Tier 2 requires the estimates of the fraction of total biomass left to decay on the ground (eq. 2.20, vol.4, ch. 2), based on national data eventually supported by default values provided in table 2.6 (combustion factor) and 2.4 (mass of fuel available for combustion).
Tier 3 requires detailed data, usually derived from on-site measurements.

***Soil***
As pointed out in the generic method chapter 2, 2006 IPCC Guidelines provides 2 separate guidance for forest soils: mineral forest soils and organic forest soils.
***Tier 1***
- *Mineral soils* - Tier 1 method assumes that forest soil carbon stock do not change with management, resulting therefore in change in SOC stocks assumed to be zero.
- *Organic soils* - Equation 2.26 (vol. 4, ch. 2) has to used to estimate $CO_2$ emission from drained forest organic soils, stratified by climate type.

***Tier 2***
Tier 2 should involve a finer stratification of management, forest type or disturbance regime, than the one used under Tier 1, taking into account national circumstances:
- *Mineral soils* - Soil organic C stocks are estimated with eq. 2.25 (vol. 4, ch. 2), based on reference soil C stocks and country-specific stock change factors for forest type (FI), management (FMG) and natural disturbance regime (FD).
- *Organic soils* - The Tier 2 approach considers the use of country specific information in application of equation 2.26 (vol. 4, ch. 2), as well as the enhancement of the stratification for climate and management systems.

***Tier 2***
Tier 3 approaches involve the use of more advanced models than Tiers 1 and 2 methods, and/or by developing a measurement-based inventory with a monitoring network. For mineral soils, Tier 3 modelling approaches can address the influence of land use and management changes on carbon dynamic, also by additional stratification by climatic zones, major forest types and management regimes.

### *3.16.3 Land converted to forest land*
The 2006 IPCC Guidelines provides methodological guidance to provide annual estimates of GHG emissions and removals from lands converted to Forest Land from different land-uses, including Cropland, Grassland, Wetlands, Settlements, and Other land, through afforestation and reforestation, either by natural or artificial regeneration (including plantations). National definition of forest, as adopted by the country, shall be applied to classify, following conversion converted areas as Forest Land. A default transition period of 20 years is suggested.

***Biomass***
All Tiers require information on areas converted to forest land over the 20 years prior to the inventory year. After the 20 years (as default value or longer transition period if justified by national circumstances), land converted to forest land should be transferred and accounted for under the subcategory forest land remaining forest land. The 2006 IPCC Guidelines provides the calculation

steps for estimating change in carbon stocks in biomass using Tier 1 method; a specific section has been included to address the uncertainty assessment.

***Tier 1***

National statistics can used as annual activity data (i.e. area); if no country data are available, aggregate information can be obtained from international data sets (FAO). The annual change in carbon stocks in biomass can be estimated using the gain-loss method (eq. 2.7, vol. 4, ch. 2), assessing:

- the annual increase in biomass carbon stock (eq. 2.9. vol. 4, ch. 2);
- Annual decrease in biomass carbon stocks due to losses (eq. 2.11. vol. 4, ch. 2).

Default parameters are provided in tables 4.1 to 4.14 (vol. 4, ch. 4).

***Tier 2***

It is based on the use of national data on:

- area annually converted to forest;
- average annual growth in biomass carbon stocks per ha on converted lands, derived usually from forest inventories (with application of eq. 2.9 and 2.10, vol.4, ch. 2)
- change in biomass carbon when non-forest land becomes Forest Land (with application of eq. 2.16, vol.4, ch. 2);
- emissions due to loss of biomass on converted land (with application of eq. 2.11, 2.12, 2.13, 2.14 vol.4, ch. 2).

***Tier 3***

It should be used when land conversion to Forest land leads to a significant carbon stock change (key category). Models should be used on country specific data, usually involving a finer spatial resolution and stratification.

***Dead organic matter***

Most likely non-forest land will not have significant dead wood or litter carbon pools.

***Tier 1***

It assumes that carbon stocks in dead wood and litter pools in non-forest land are zero, and that carbon in dead organic matter pools increases linearly to the value of mature forests in the transition period (default = 20 years).

***Tier 2 and 3***

The *Gain-loss* (eq. 2.18, vol. 4, ch. 2) or the *stock-difference* (eq. 2.19, vol. 4, ch. 2) can be used to estimate the carbon stock changes in the dead wood and litter pools.

***Soil***

The total change in soil C stocks for Land Converted to Forest Land is computed using equation 2.24 (vol. 4, ch. 2), which sums the change in soil organic C stocks for mineral soils and organic soils; and carbon stock changes for inorganic soil C pools (Tier 3 only).

2006 IPCC Guidelines provides default values to be used in the estimation process for mineral soils: default reference C stocks (table 2.3, vol. 4, ch. 2), default stock change factors (vol. 4, ch. 4 for Forest Land in 4.2.3.2, ch. 5 for Cropland in Section 5.2.3.2, ch. 6 for Grassland in 6.2.3.2, ch. 8 for Settlements in 8.2.3.2, ch. 9 for Other Land in 9.3.3.2).

Tier 1 emission factors to be applied for organic soils are given in table 4.6 (vol. 4, ch. 4). The calculation steps for estimating change in carbon stocks in soils using Tier 1 is provided in the section 4.3.3.4 (vol. 4, ch. 4).

***Tier 1***

- *Mineral soils* - Change in soil organic C stocks can be estimated using equation 2.25 (vol. 4, ch. 2).
- *Organic soils:* Equation 2.26 (vol. 4, ch. 2) has to used to estimate $CO_2$ emission from drained forest organic soils, stratified by climate type.

***Tier 2***

It should involve the use of a country specific $SOC_{ref}$ and/or stock change factors, with a eventual more disaggregate data, taking into account national circumstances.

- *Mineral soils:* Soil organic C stocks are estimated with eq. 2.25 (vol. 4, ch. 2), based on reference soil C stocks and country-specific stock change factors for forest type ($F_I$), management ($F_{MG}$) and natural disturbance regime ($F_D$).
- *Organic soils:* The Tier 2 approach considers the use of country specific information in application of equation 2.26 (vol. 4, ch. 2), as well as the enhancement of the stratification for climate and management systems.

***Tier 3***
It involves the use of more detailed and advanced models than Tiers 1 and 2 methods, based on measurement-based approaches.

### *3.16.4 Non-$CO_2$ greenhouse gas emissions from biomass burning*

Method for estimation of GHG emission in forest land remaining forest land, as well as in land converted to forest land, is described in eq. 2.27 (vol.4, ch. 2); in the same chapter 2 of the 2006 IPCC Guidelines default values for Tier 1 approach or elements to be considered under Tier 2 approach (tables 2.4,2.5,2.6, vol.4, ch. 2). The decision tree (fig. 2.6, vol.4, ch. 2) can help in selecting the appropriate Tier for estimates of GHG emissions from fire.

**Box 3.23** – *Forest land*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Forest land**

- Aiming to produce more accurate estimates of carbon stock changes, the forest land area can be stratified by climate or ecological zones, and classified by forest types, disturbance regime, management practices, etc.; it is a good practice to adopt the same stratification to each carbon pool.
- Using higher Tiers methods, countries may develop derive soil organic C estimates directly without using reference C stocks and adjustment factors, usually deriving them from ad-hoc surveys or measurements.
- To estimate carbon stock changes in land converted to forest land, it is key the assessment of the land use type and management practice of the land under conversion to forest land.
- A glossary for forest land is provided in the Annex 4A.1.

**Box 3.24** – *Improvements for forest land in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Improvements for forest land in the 2019 Refinement**

In the 2019 Refinement, a guidance has been included on:

- Use of allometric models to be used with country specific data to estimate carbon stocks (IPCC 2019 Refinement);
- Use of biomass density maps *(IPCC 2019 Refinement)*
- Method for Estimating the Change in Mineral Soil Organic Carbon Stocks from Biochar Amendments (IPCC 2019 Refinement, Appendix 4)

Furthermore, default emission factors, parameters and values to be used for estimate carbon stock changes have been updated, as:

- ratio of below-ground biomass to above-ground biomass (IPCC 2019, table 4.4);
- above-ground biomass in natural forests (IPCC 2019, table 4.7), in forest plantations (IPCC 2019, table 4.8);
- above-ground net biomass growth in natural forests (IPCC 2019, table 4.9) and in tropical and subtropical plantation forests (IPCC 2019, table 4.10);
- reported mean annual increment (growth rate of merchantable volume) values for some plantation forest species (IPCC 2019, table 4.11).

## 3.17 Cropland (4.B)

### *3.17.1 Overarching changes*

In the 2006 IPCC GLs Cropland is a completely new section with respect to 1996 IPCC GLs. In the latter guidelines, emissions/removals related to Cropland was included only in the forest land and grassland converted to agricultural land category. In the 2006 IPCC GLs, cropland is considered as a land use category per se.
Cropland category definition is included in the chapter 3 of the 2006 IPCC Gls: a broad range of land cover and management types used for plant origin food and feed production which fall outside the forest land definition used by the country is included; it may also include perennial woody crops (as, for example, orchards, coffee, rubber plantations and vineyards) and agroforestry systems.

Cropland analyses follow the main rules selected for LULUCF. Therefore, cropland emissions/removals should be estimated:

- separately for each subcategory: "Cropland remaining cropland" and "Land converted to Cropland";
- considering the different C pools;
- following the main methodologies described in the 2006 IPCC GLs, Vol. 4, Ch. 2 (IPCC, 2006);
- stratifying activity data by management practices, ecological zones and climate types (as described in section 10-12 of this report). This stratification is fundamental to consider all possible effects of these parameters on C stocks and emission factors (EF) of the five C pools.

Cropland can be further disaggregated on the basis of presence of permanent biomass tissues (therefore into annual and perennial crops) and species types or categories, allowing the consideration of C stock and emission factors variability of all the carbon pools.

### *3.17.2 Cropland remaining cropland*

It includes croplands that have not been subjected to land conversions for at least 20 years (default time-period). Carbon pools equilibrium may be reached in a different transition period as a function of land use, climatic zones and soil categories. Countries that can justify a different time-period selection can be use it unless it is use constantly for the different land-use categories.

***Biomass***

The Aboveground biomass is generally assumed as an ephemeral carbon pool for the annual crops, while it could be significant for the perennial woody vegetations in many countries. Therefore, it is generally not required to account for it in the annual crops, while it is fundamental in the emission/removal estimates related to perennial woody vegetations.

The *Gain-loss* method (eq. 2.7, vol. 4, ch. 2) can be applied for all the Tier levels, while the *stock-difference* (eq. 2.8, vol. 4, ch. 2) one can be applied only for higher tiers (tier 2 and Tier 3).

***Tier 1***

The *Gain-loss* method has to be applied under Tier 1 approach, assuming that:

- all carbon in perennial woody biomass removed is emitted in the reporting year, during the biomass clearing or replanting year;
- perennial woody crops accumulate carbon for an amount of time equal to a nominal harvest/maturity cycle.

The amount of biomass removed is generally assumed equal to the total biomass at the end of the growing cycle, a parameter that depends on cropland type, ecological region, climatic zone and soil category. On the opposite, the carbon gain is mainly caused by permanent tissue growth util the end of growing cycles, a time period which depends on crop species/types and climatic zones. Default coefficients are summarised in Table 5.1-5.3 (vol. 4, ch.5). Using Tier 1 approach, the belowground biomass is assumed to be constant over time both in the annual and perennial crop systems.

Regarding biomass losses from removals, fuelwoods and disturbances, the default methodology assumes that emission do occur in the same year of biomass lost. Unfortunately, international database (e.g. FAO) only provide total roundwood and fuelwood consumption without any separation between the land use category origin (i.e. forest land, cropland,…). For this reason, when these data are used for the inventory preparation, inventory compilers need to pay particular attention in avoiding double counting estimations. Default assumption considers the forest land as the only category considered as roundwood and fuelwood.

***Tier 2 and 3***

Both *Gain-loss* method and *stock-difference* methods can be applied, considering the use of country-specific or region-specific estimates of biomass carbon stock, stratified according to cropland types and management practices.

***Dead organic matter***

Dead organic matter pools (deadwood and litter) can be significantly affected by country-specific management practices and species. These pools are not present (and should not be estimated) in annual crops, while these pools could be significant in perennial woody crops, as orchards and agroforestry systems.

***Tier 1***

However, due to the limited number of studies on these pools in perennial crops, the Tier 1 methodology considers the dead organic matter C stocks as at equilibrium in woody crops remaining in the same land use category.

***Tier 2 and 3***

Both gain-loss and stock-difference methodologies can be used, considering that the latter one may not be suitable for region characterised by variable climatic conditions. Carbon fraction can significantly vary as a function of the stage of decomposition of the dead organic matter, however 2006 IPCC GLs suggested to use 0.5 (C/dry matter).

***Soil***

The key driver for the change in the SOC stock in mineral soils is the change in management practices. These practices can significantly vary, depending on the national circumstances and crops types: among them, the more significant practices are: residue management, tillage, fertilization, crop type and cropping intensity, irrigation.

***Tier 1 and 2***

- *Mineral soils* - Change in soil organic C stocks can be estimated using equation 2.25 (vol. 4, ch. 2), which considers both the reference soil organic carbon stock of a specific land stratification (soil and climate parameter) and stock change factors related to land use, land management and input in the same land stratification pattern. Default values are available in table 2.3, for reference SOC, and table 5.5, for stock change factors, considering a 20-years default time-period and the upper 30 cm of the soil profile. In case no national data are available and inventory agencies need to refer to international databases (e.g. FAO database which are only broadly disaggregated into main sub-categories), the collected data can be disaggregated on the basis of national expert judgements. The activity data and stock change factors must be characterised by the same disaggregation approach to be used. This is a topic that should be clearly understood to carefully plan and optimise future inventory improvements.
- *Organic soils* - Change in soil organic C stocks can be estimated using equation 2.26 (vol. 4, ch. 2). Default values are available in table 5.5.

For tier 2, country specific data and parameters can be based on specific national circumstances.

***Tier 3***

Tier 3 level is generally based on country-specific dynamic models. Management practices may also significantly affect emission/removals from soil inorganic C. This pool should be considered only applying a tier 3 methodology.

### *3.17.3 Land converted to Cropland*

Lands that have been converted into cropland within the last 20 years (default time-period) are included in this sub-category. Other time-period may be considered reflecting national circumstances.

***Biomass***

***Tier 1***

It assumes that the biomass of the previous land use is completely lost (i.e. removed) in the year of land-use change and that, after the first year following land-use change, the C stock cropland biomass correspond to default values suggested in table 5.9 (2006 IPCC GLs, Vol.4, Ch.5). The methodological approach to estimate biomass C stock change in land converted to cropland is based on equation 2.16 (2006 IPCC GLs, Vol.4, Ch.2). In the following years to reach the new steady state (20 years as default) the biomass of woody crops must be estimated according to "cropland remaining cropland" methodology.

***Tier 2 and 3***

Higher tier levels may consider country-specific biomass values, the fact that part of the biomass of the previous land use may remain after land-use changes, the biomass decay processes (time), the transition of biomass carbon into other C pools according to confusion matrixes.

***Dead organic matter***

2006 IPCC GLs assume that C stock changes in the DOM in land converted to cropland follow a two-phase approach: an abrupt variation in the year of land use change, and the progressive variation in the following 19 years after the conversion (using the 20 years default time-period) until reaching a steady-state.

***Tier 1***

The abrupt DOM changes in the first phase should be estimated using equation 2.23, considering that the litter and deadwood biomass in cropland system is likely to be zero unless country-specific conditions. Default values for deadwood and litter C pools in perennial woody crops are extremely

limited in the literature. Local research are encouraged to fill this gap. Tier 1 methodology assumes that no carbons stock change occurs in the second phase after land conversion into grassland.

***Tier 2 and 3***

For Tier 2 and Tier 3 levels, both Gain-Loss (eq. 2.18) and Stock-Difference methods (eq. 2.19) can be used as a function of local data availability.

***Soils***

Soil organic carbon stock changes due to land converted to cropland follow the same methodological approach described for cropland remaining cropland. For mineral soils, specific stock change factors should be considered as a function of previous land use type before the conversion into cropland (see other land use sections). Transient land-use conversion to cropland (as crop-fallow cycles) in mineral soils should be considered as a specific case. Table 5.10 (2006 IPCC GLs, Vol.4, Ch.5) summarised ad hoc soil stock change factors for these transient land-use conversions.

In the 2006 IPCC Guidelines, emission factors of C stock changes for cultivated organic soils changed from 1 to 5 tonnes C $ha^{-1}yr^{-1}$. This will lead to a significant increase in emissions for countries with high shares of organic soils.

**Box 3.25** – *Improvements for cropland in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Improvements for cropland in the 2019 Refinement**

In the 2019 Refinement, some improvements were made for cropland:

- default coefficients for different agroforestry systems were updated, in particular ones containing perennial species;
- default biomass carbon stocks present on land converted to cropland in the years following conversion were updated;
- a new Tier 2 steady-state method for estimating mineral soil organic carbon stock changes was introduced.

## 3.18 Grassland (4.C)

### *3.18.1 Overarching changes*

In the 2006 IPCC Guidelines, a wider spectrum of emissions and removals related to Grassland land use are considered with respect to the 1996 IPCC GLs. Dead organic matter C pools and belowground biomass are included in the logical methodological procedures in addition to specific land management changes. Main differences between 1996 and 2006 IPCC GLs are related to the methodological procedure to estimate C stock changes in biomass and soil pools, the inclusion of emissions caused by natural disturbances and wildfires in managed grasslands, the estimation of emissions/removals caused by different land uses (not only forest land) converted into grassland, and the extension of the previous methods for estimation of non-$CO_2$ emission due to biomass burning in all grassland typologies.

The grassland category may include a wide variety of vegetation types that does not fit the forest and cropland definition and all land that can not be considered nor wetland, nor settlement, nor other land. This wide spectrum of vegetation types span between extensive herbaceous rangeland to dense shrubs cover (e.g. Mediterranean maquis), from intensively managed (e.g. irrigated and fertilized) pasture to savannahs. Woody vegetation types that fall below forest land thresholds definition can be considered grassland.

As all the other land categories, the 2006 IPCC GLs disaggregate Grassland by soil type, climatic zone, management practices and "Grassland remaining Grassland" or "Land converted to Grassland". If no activity data are available to differentiate these two subcategories, the default approach is to consider all grasslands under "Grassland remaining Grassland".

### *3.18.2 Grassland remaining Grassland*

It includes grasslands that have not been subjected to land conversions for at least 20 years (default time-period). Therefore, main emissions/removals estimates related to this subcategory are due to changes in land cover (e.g. from herbaceous grassland to shrubland) and management practices (e.g. from extensive to overgrazed pasturelands).

***Biomass***

Many grassland types are characterised by a reduce amount of carbon stored in the aboveground pool as it limited by natural and anthropogenic pressures as fires and annual senescence, and grazing and woody biomass harvesting, respectively. Belowground biomass could be a substantial C pool, however it is characterised by a general lack of data in several ecosystems because these data needs of laborious and difficult procedures to be measured. Many studies estimate this pool by means of specific root-to-shoot ratios, as it is suggested in the 2006 IPCC GLs for tier 2 methodology (Vol.4, Ch.6, Table 6.1) when no ecosystem-specific data are not available.

***Tier 1***

It assumes that no change in biomass occur in grassland remaining grassland, although a management change can cause a significant C stock change in this pool.

***Tier 2 and 3***

Both methodological procedures (gain-loss and stock-difference methods) can be applied; national methodology may be developed, based on country-specific and sophisticated models. However, it may not be recommended to use the stock-difference methods in region with variable climates. Biomass stock change procedure consider separately changes in woody biomass (default value of 0.5 C/dry biomass weight) and herbaceous biomass (default value of 0.47 C/dry biomass weight).

***Dead organic matter***

In grassland ecosystems, the litter and dead wood accumulation could be significantly influenced by several parameters as the ratio between woody and herbaceous species cover, disturbances (e.g. fire events) and the time since last disturbance.

***Tier 1***

As for biomass carbon pools, tier 1 methodology assumes that dead wood and litter do not change in grassland remaining grassland.

***Tier 2 and 3***

Both gain-loss and stock-difference methodologies can be used, considering that the latter one may not be suitable for region characterised by variable climatic conditions. Carbon fraction can significantly vary as a function of the stage of decomposition of the dead organic matter, however 2006 IPCC GLs suggested to use 0.5 (C/dry matter) for dead wood and 0.4 (C/dry) matter for litter in grassland whenever country-specific data are not available.

***Soil***

Soil carbon in grassland remaining grassland can be influenced by management practice input (e.g. fertilization), by the excrements of grazing animals, but also by plant species (e.g. N-fixing ones), and by fires and other natural disturbances and by leaching losses. Inorganic soil C changes can also be estimated but only applying a Tier 3 methodology.

***Tier 1 and 2***

- *Mineral soils* - Change in soil organic C stocks can be estimated using equation 2.25 (vol. 4, ch.2). Default values are available in table 2.3, for reference SOC, and table 6.2, for stock change factors, considering a 20-years default time-period and the upper 30 cm of the soil profile.
- *Organic soils* - Change in soil organic C stocks can be estimated using equation 2.26 (vol. 4, ch.2). Default values are available in table 6.3.

For tier 2, country specific data and parameters can be based on specific national circumstances.

***Tier 3***

Tier 3 level is generally based on country-specific dynamic models.

### *3.18.3 Non-$CO_2$ emission from biomass burning*

GHG emissions from biomass burning can be significant in some countries where fire is a disturbance that frequently occurs (by natural or anthropic origin) and regulate vegetation dynamics. Differently from 1996 GLs, the 2006 ones give the possibility to estimate non-$CO_2$ emissions from woody and herbaceous aboveground biomass, and from dead organic matter pools. For Tier 1 and 2, the suggested methodology follows equation 2.27 (vol.4, ch.2) with different stratification levels for land, climatic, and burned period parameters. Default values are summarised in Table 2.4, 2.5 and 2.6 (vol.4, ch.2). Process models based on country-specific data are request for the application of Tier 3 methodology. Annual activity data are recommended for all methodological approaches so to capture possible interannual variability in fires events (e.g. El Niño, unusually dry years). Under all Tier level methodologies, the use of national activity data is recommended. If they are not available, global fire maps can be used considering that these products usually include only a portion of all the areas affected by fires events.

### *3.18.4 Land Converted to Grassland*

***Biomass***

Estimation of changes in biomass requires an estimate of changes in above-ground vegetation and changes in below-ground biomass. Countries should use the highest tier possible given national circumstances. It is good practice to use a Tier 2 or Tier 3 approach if carbon emissions and removals in Land Converted to Grassland is a key category and if the sub-category of biomass is considered significant.

***Tier 1***

The changes in biomass carbon stock on Land Converted to Grassland under Tier 1 should be estimated using Equation 2.15 (2006 IPCC GLs, Vol.4, Ch.2). It assumes that the biomass of the previous land use is completely lost (i.e. removed) in the year of land-use change and that, and residual biomass ($B_{AFTER}$) is thus assumed to be zero, (i.e., the land is cleared of all vegetation before grassland vegetation is established), implying that there is not a transfer of biomass from the biomass pool to the other carbon pools. Default biomass stocks present on grassland, after the conversion from other land use are provided in the table 6.4 (2006 IPCC GLs, Vol.4, Ch.6).

***Tier 2 and 3***

Higher tier levels consider a two-phase approach: an abrupt change in biomass in the year of land use change, and the progressive variation in the following 19 years after the conversion (using the 20 years default time-period) until reaching a steady-state. Under Tier 2 approach, it is good practice to apportion transfers of carbon between pools, in relation to the phase 2 of the abovementioned approach. The immediate and abrupt carbon stock change in biomass due to Land Converted to Grassland under Tiers 2 and 3 will be estimated using Equation 2.16 in Chapter 2 (2006 IPCC GLs, Vol.4, Ch.2), where $B_{AFTER}$ is assumed to be zero. During the transition period, the changes in biomass carbon can be estimated by using the gain loss method (equation 2.7, 2006 IPCC GLs, Vol.4, Ch.2) or the stock-difference method (equation 2.8, 2006 IPCC GLs, Vol.4, Ch.2). Countries may consider country-specific biomass values, the fact that part of the biomass of the previous land use may remain after land-use changes, the biomass decay processes (time), the transition of biomass carbon into other C pools according to confusion matrixes.

***Dead organic matter***

2006 IPCC GLs assume that C stock changes in the DOM in land converted to cropland follow a two-phase approach: an abrupt variation in the year of land use change, and the progressive variation in the following 19 years after the conversion (using the 20 years default time-period) until reaching a steady-state.

***Tier 1***

The change in DOM carbon stock on Land Converted to Grassland under Tier 1 should be estimated using Equation 2.23 (2006 IPCC GLs, Vol.4, Ch.2), where $C_0$ equals zero and $T_{on}$ equals 1. The Tier 1 default assumes removal of all dead wood and litter during conversion and that there is no dead wood or litter that remains or accumulates in Land Converted to Grassland. There are no default values available for dead wood or litter in most systems.

***Tier 2 and 3***

Higher tier levels require greater disaggregation than that used in Tier 1. Activity data should be reported by ecological zone and management regimes. The immediate and abrupt carbon stock change in biomass due to Land Converted to Grassland under Tiers 2 and 3 will be estimated using Equation 2.23 in Chapter 2 (2006 IPCC GLs, Vol.4, Ch.2). During the transition period, the changes in carbon can be estimated by using the gain loss method (equation 2.7, 2006 IPCC GLs, Vol.4, Ch.2) or the stock-difference method (equation 2.8, 2006 IPCC GLs, Vol.4, Ch.2). Countries may consider country-specific own methodologies and parameters for estimating changes in DOM.

***Soils***

The changes in soil carbon stock on Land Converted to Grassland under Tier 1 should be estimated using Equation 2.25 (2006 IPCC GLs, Vol.4, Ch.2), using for the pre-conversion C stocks are data and information on stock change factors for another land use.

Higher Tiers methods for mineral soils also uses Equation 2.25 (2006 IPCC GLs, Vol.4, Ch.2), involves country-specific or region-specific reference C stocks and/or stock change factors and more disaggregated land-use activity and environmental data.

**Box 3.26** – *$CO_2$ emissions from organic soils*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**$CO_2$ emissions from organic soils**

- In the 2006 IPCC Guidelines, emission factors of C stock changes for cultivated organic soils changed from 1 to 5 tonnes C ha-1yr-1. This will lead to a significant increase in emissions for countries with high shares of organic soils.

**Box 3.27** – *Improvements for grassland in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Improvements for grassland in the 2019 Refinement**

In the 2019 Refinement, a few improvements were made for grassland, with the introduction of:

- new default C stock change factors for mineral soils;
- new classification scheme for grazing management systems.

## 3.19 Wetlands (4.D)

### *3.19.1 Overarching changes*

The 2006 IPCC Guidelines include methods to estimate GHG emissions from managed wetlands (vol. 4, ch. 7, table 7.1), providing methodologies for estimation of:

- $CO_2$ and $N_2O$ emission from *peatlands* for wetlands remaining wetlands (vol. 4, ch. 7, section 7.2.1.1 and section 7.2.1.2);
- $CO_2$ and $N_2O$ emission from *peatlands* for land converted to wetlands (vol. 4, ch. 7, section 7.2.2.1 and section 7.2.2.2).

Methods for estimation of $CH_4$ emissions are contained in an appendix as a basis for future methodological developments[10], due to limited availability of scientific information.

$CO_2$ emissions from *flooded land remaining flooded land* are considered to be covered by carbon stock change estimates of land uses and land-use change (e.g., soils) upstream of the *flooded land*; and $N_2O$ emissions from *flooded land* are considered to be included in the estimates of indirect $N_2O$ from agricultural or other run-off, and waste water. Finally, emissions and removals from fires in wetlands are not estimated, on the basis of the assumption that these are not occurring ("NO").

Total $CO_2$ emissions from wetlands are estimated as the sum of emissions from the two types of managed wetlands: *managed peatlands* and *flooded land*.

### *3.19.2 Peatlands remaining peatlands*

$CO_2$ emissions from lands subject to peat extraction derives from on-site emissions from peat deposits during the extraction phase, and off-site emissions from the horticultural (non-energy) use of peat (vol. 4, ch. 7, eq. 7.2). Under Tier 1, methane emissions are assumed to be insignificant in these drained peatlands. The default approach for estimating $N_2O$ emissions from lands managed for peat extraction excludes emissions from the decay of organic nitrogen in horticultural peat, to avoid double-counting $N_2O$ emitted from the use of fertilizers, being the latter the key driver for $N_2O$ emissions.

***Tier 1***

$CO_2$: Equations 7.3, 7.4 and 7.5 (vol. 4, ch. 7) have to be applied to estimate the on-site $CO_2$ emissions and the horticultural use of peat. To be noted that the abovementioned eq. 7.4 for on-site $CO_2$ emissions is applied to the total area of managed peatlands, including land being converted to peatlands and abandoned peatlands, unless abandoned peatlands were converted to another use, in which case emissions should be attributed to the new land use. Default emission and conversion factors are provided in Tables 7.4 and 7.5 (vol. 4, ch. 7), respectively.

$N_2O$: Equation 7.7 (vol. 4, ch. 7) should be used to estimate $N_2O$ emissions from drained wetlands. Default emission factors are provided in Tables 7.6 (vol. 4, ch. 7).

***Tier 2 and 3***

Country-specific emission factors and parameters, spatially disaggregated to reflect regionally important practices and dominant ecological dynamics should be used under higher Tiers approaches. The on-site $CO_2$ emissions can be estimated with eq. 7.6 (vol. 4, ch. 7). Countries using higher Tiers should obtain national peat production data and the corresponding peatlands areas. Concerning $N_2O$

[10] 2006 IPCC Guidelines for National Greenhouse Gas Inventories – Specific Developments

emissions, a further stratification of activity data should be used, also by providing a comprehensive representation of the dynamics of $N_2O$ emissions and removals on managed peatlands.

### *3.19.3 Land being converted for peat extraction*

***Tier 1***

$CO_2$ and non-$CO_2$: Under a Tier 1 approach, the methodology is the same of the subcategory peatlands remaining peatlands (vol.4, ch.7, section 7.2.1 for $CO_2$ and section 7.2.1.2 for non $CO_2$), since the activity data do not distinguish between peatlands under peat extraction (*peatlands remaining peatlands*), and those being converted for peat extraction.

***Tier 2 and 3***

$CO_2$: The peat extraction cycle has three phases, the first one of which being the development or conversion for peat extraction, characterized by extensive drainage work, but little peat extraction. The default transition period for Land Being Converted for Peat Extraction is five years. The three elements to be considered to estimate the $CO_2$-C emissions during land conversion for peat extraction (eq.7.8, vol. 4, ch. 7) are related to the change in carbon stocks in living biomass and in dead organic matter pools, and from soils during drainage. The estimation process for the carbon stocks in living biomass and DOM pools is linked to the pre-clearing standing vegetation (section 5.3, vol.4, ch.5) if the pre-clearing standing vegetation in included in *forest land* or *grassland*). If the clearing is carried out with fires, specific guidance on GHG emissions from burning should be used (vol.4, ch.2). Equation 7.9 (vol. 4, ch.7) should be used to estimate emissions from soil during drainage. Tier 3 methods involve a comprehensive representation of the dynamics of $CO_2$ emissions and removals on *land being converted for peat extraction.* Country-specific emission factors and parameters should be used under higher Tiers approaches.

### *3.19.4 Flooded land*

No methodologies are provided for *flooded land remaining flooded land*, assuming that that $CO_2$ and $N_2O$ emissions occurring on flooded lands are already covered by methodologies described in other sectors. Emissions of non-$CO_2$ gases from *land converted to flooded land* are covered in Appendix 3.

***$CO_2$ emissions from land converted to flooded land***

Equation 7.10 (vol. 4, ch. 7) should be used to estimate the carbon stock change due to land conversion to permanently *flooded land*, assuming that the carbon stock after conversion is zero and estimating the carbon stock of the land prior to conversion following the method for living biomass described for various land-use categories.

No guidance is provided on carbon stock changes from soils due to land conversion to *flooded land* at this time.

**Box 3.28** – *Improvements for wetlands in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Improvements for wetlands in the 2019 Refinement**

In the 2019 Refinement, new guidance for flooded land is provided, including a decision trees to support the inventory compiler in the attribution of flooded land type as well as to choose the Tier level to estimate $CO_2$ and $CH_4$ from waterbodies. $CH_4$ emission factors and parameters for reservoirs and for other constructed waterbodies have been included in the guidance.

Guidance on how to estimate $CO_2$ and non-$CO_2$ emissions from land converted to flooded land, in the five carbon pools, is provided in the 2019 Refinement, also including the relevant emission factors and parameters.

## 3.20 Settlements (4.E)

### *3.20.1 Overarching changes*

Overall, the 2006 IPCC Guidelines have maintained the same basic structure and methods of the IPCC GPG for LULUCF, consolidating a number of previously optional categories that were contained in the appendices of IPCC GPG for LULUCF as the basis of future methodological work, such as the terrestrial carbon stocks in settlements.

The changes in C stocks in settlements remaining settlements are now part of the main body of the 2006 IPCC Guidelines, while they were previously included in an Annex to IPCC GPG for LULUCF.

This chapter provides methods for estimating carbon stock changes and GHG emissions and removals associated with changes in biomass, dead organic matter (DOM), and soil carbon on lands classified as settlements.

### *3.20.2 Settlements remaining settlements*

Settlements are defined as including all developed land, i.e. residential, transportation, commercial, and production (commercial, manufacturing) infrastructure of any size, unless it is already included under other land-use categories. The 2006 IPCC Guidelines provides the calculation steps for estimating change in carbon stocks in biomass using 2 the options under Tier 2 method.

***Biomass***

The general method for biomass carbon stock change follows the approach in Equation 2.7 (vol. 4, ch. 2). Biomass changes is the sum of the three components: trees, shrubs and herbaceous perennial (eq. 8.1, vol. 4, ch. 8). The 2006 IPCC Guidelines provides the calculation steps for estimating change in carbon stocks in biomass using 2 the options under Tier 2 method.

***Tier 1***

It assumes that no change in biomass carbon stocks.

***Tier 2***

Two options for Tier 2 estimation are provided in the 2006 Guidelines:

- Tier 2a: uses changes in carbon stocks per unit of plant crown cover area as a removal factor (eq. 8.2, vol. 4, ch. 8). Default removal factor for tree biomass is provided in the table 8.1.
- Tier 2b: changes in carbon stocks per number of plants as a removal factor (eq. 8.3, vol. 4, ch. 8). Default carbon accumulation rates for tree species classes are provided in the table 8.2.

***Tier 3***

It is based either on Tier 2 methods with more detailed measurements of parameters at disaggregated level for different settlement systems, or on a *stock difference* approach (eq. 2.8, vol. 4, ch. 2). If the subcategory settlements remaining settlements is a key category, countries should collect appropriate activity data and emissions factors.

***Dead organic matter***

Based on the available scientific studies on the accumulation rate of dead wood in settlements and litter accumulation, the accumulation rate of the litter component of DOM to set to zero. The default carbon fraction of dead wood and litter is 0.50 t C $(t\ d.m.)^{-1}$.

***Tier 1***

The dead wood and litter stocks are at equilibrium, and so there is no need to estimate the carbon stock changes for these pools

***Tier 2 and 3***

The *Gain-loss* (eq. 2.7, vol. 4, ch. 2) or the *stock-difference* (eq. 2.8, vol. 4, ch. 2) can be used to estimate the changes in dead wood and litter carbon due to changes in tree cover and related carbon stock changes.

***Soil carbon***

Based on the available scientific studies on the accumulation rate of dead wood in settlements

***Tier 1***

- *Mineral soils* - Change in soil organic C stocks are assumed to be zero
- *Organic soils* - Change in soil organic C stocks can be estimated using equation 2.26 (vol. 4, ch. 2). Default values are available in table 5.6 (vol.4, ch. 5) and in table 6.3 (vol. 4, ch. 6).

***Tier 2***

- *Mineral soils* - Change in soil organic C stocks can be estimated using equation 2.25 (vol. 4, ch. 2), involving country specific $SOC_{ref}$ and/or stock change factors.
- *Organic soils* - Change in soil organic C stocks can be estimated using equation 2.26 (vol. 4, ch. 2).

For tier 2, country specific data and parameters can be based on specific national circumstances.

***Tier 3***

It involves the use of dynamic models, usually based on nationally measured data.

### *3.20.3 Land converted to settlements*

***Biomass***

The general method for biomass carbon stock change follows the approach in equations 2.15 and 2.16 (vol. 4, ch.2). The annual change in biomass carbon stocks due to land conversion is estimated by multiplying the area converted annually to settlements by the difference in carbon stocks between biomass in the system prior to conversion ($B_{Before}$) and that in the settlements after conversion ($B_{After}$).

***Tier 1***

It assumes that $B_{After}$ is zero, assuming that all biomass is cleared when preparing a site for settlements; eq. 2.15 (vol. 4, ch. 2) has to applied to estimate the net change in carbon stocks on land converted to settlements. Default values for biomass before conversion ($B_{Before}$) are available in table 8.4 (vol.4, ch.8).

***Tier 2 and 3***

For tier 2, country specific data and parameters can be based on specific national circumstances. Using Tier 3, countries can estimate the carbon stock changes with the *stock difference* method (eq. 2.8, vol. 4, ch.2).

***Dead organic matter***

The carbon fraction of dead wood and litter is variable and depends on the stage of decomposition; a default value of 0.50 and 0.4 t C (t d.m.)$^{-1}$ can be used for carbon fraction of dead wood and litter, respectively.

***Tier 1***

It assumes that all carbon contained in n dead wood and litter is lost during conversion. Default values for forest litter prior to conversion are provided in Table 2.2 (vol. 4, ch.2), noting that no default values are available for dead wood or litter in most systems. Carbon stocks in litter and dead wood pools in all non-forest land categories are assumed to be zero.

***Tier 2 and 3***

Nationally measured data on dead wood and litter for different settlements categories, as well as decomposition rates and country-specific values for carbon transfer can be used. The *Gain-loss* (eq. 2.7, vol. 4, ch.2) or the *stock-difference* (eq. 2.8, vol. 4, ch.2) can be used to estimate the changes in dead wood and litter carbon for land converted to settlements.

***Soil carbon***

***Tier 1***

- *Mineral soils* - Change in soil organic C stocks can be estimated using equation 2.25 (vol. 4, ch. 2), using the default values for SOCref (table 2.3, vol. 4, ch.2) and stock change factors (vol. 4, ch.4 for Forest Land in Section 4.2.3.2, ch.5 for Cropland in 5.2.3.2, ch.6 for Grassland in 6.2.3.2, and ch.9 for Other Land in 9.3.3.2). It is *good practice* to use the following assumptions:
  - Based on the proportion of settlements area that is paved over, product of of $F_{LU}$, $F_{MG}$ and $F_I$ is 0.8 times the corresponding product for the previous land use;
  - Values for improved grassland for the proportion of settlements area that is turfgrass (vol. 4, ch.6, table 6.2);
  - no-till FMG values (vol. 4, ch.5, table 5.5) for the proportion of settlements area that is cultivated soil;
  - all stock change factors equal to 1 for the proportion of settlements area that is wooded.
- *Organic soils* - Change in soil organic C stocks can be estimated using equation 2.26 (vol. 4, ch.2).

***Tier 2***

- *Mineral soils* - Change in soil organic C stocks can be estimated using equation 2.25 (vol. 4, ch.2), involving country specific $SOC_{ref}$ and/or stock change factors.
- *Organic soils* - Change in soil organic C stocks can be estimated using equation 2.26 (vol. 4, ch.2); country specific data and parameters can be based on specific national circumstances.

***Tier 3***

It involves the use of more detailed and country-specific models and/or measurement-based approaches.

**Box 3.29** – *Settlements*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Settlements**

- For Tiers 2a and 2b, the default assumption for annual loss in biomass carbon stocks (ΔCL) is that the average age of the tree population is less than or equal to 20 years is zero, assuming that urban trees are net sinks for carbon when they are actively growing and that the active growing period (AGP) is roughly 20 years, depending on tree species, planting density, and location. Countries can define AGP depending on their circumstances.
- A specific chapter for fires for settlements remaining settlements has been included in the 2006 IPCC Guidelines. However, such estimates are often challenging as they require data concerning urban tree formations, which many countries lack.

**Box 3.30** – *Improvements for settlements in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Improvements for settlements in the 2019 Refinement**

In the 2019 Refinement, further guidance is provided for Tier 2 and Tier 3 methods, as well as:

- Updated default crown cover area based growth rates for Tier 2A (table 8.1, vol. 4, ch. 8);
- Updated default average annual carbon accumulation per tree for Tier 2B (table 8.2, vol. 4, ch. 8);
- Default biomass carbon stocks removed due to land conversion to settlements (table 8.4, vol. 4, ch. 8).

## 3.21 Harvested wood products (3.G)

### *3.21.1 Overarching changes*

The 2006 IPCC Guidelines provide different approaches to estimate the $CO_2$ emissions and removals related to the Harvested Wood Products (HWP); the approaches, described in the Annex 12.A.1 to the 2006 Guidelines (vol. 4, ch. 12), are: **the stock-change approach, the atmospheric flow approach and the production approach**. In order to make estimates of the HWP contribution to $CO_2$ emissions and removals for the various approaches, a generic set of annual variables, summarized in table 12.1, vol. 4, ch. 12) can be used to estimate HWP emissions and removals using any of the currently proposed approaches. The HWP chapter in the 2006 guidelines has been remarkably revised in the 2019 Refinement; the use of the guidance provided in the 2019 Refinement is strongly recommended to carry out an accurate estimate of HWP emissions and removals, considering the clearer description of the approaches already included in the 2006 Guidelines, and the updated factors and parameters to be used in the estimation process.

***Annual change in carbon stock in HWP from domestic consumption and domestic harvest***

Annual change in carbon stock in a) HWP in use (variable 1A), and b) HWP in solid waste disposal sites (SWDS) (variable 1B), in the reporting country, from **domestic consumption,** is estimated as:

$$\Delta C_{HWP\ DC} = \Delta C_{HWP\ IU\ DC} + \Delta C_{HWP\ SWDS\ DC}$$

Annual change in carbon stock in a) HWP in use (variable 2A), and b) HWP in solid waste disposal sites (variable 2B), where the wood in the products came from **domestic harvest** in the reporting country. This includes carbon release from all wood harvested in the country including wood that is exported but excluding imports.

$$\Delta C_{HWP\ DH} = \Delta C_{HWP\ IU\ DH} + \Delta C_{HWP\ SWDS\ DH}$$

***Tier1***

The HWP Variables 1A,2A, 1B and 2B are estimates of annual changes in stock of HWP carbon which are each estimated using a flux-data method with lifetime-analysis. The decay of HWP is assumed to be of first-order. The carbon inflow to the pool is estimated from historical production or consumption rates of HWP.

Waste Sector Tier 1 methods are used to estimate change in HWP carbon stock in SWDS (Variable 1B) (2006 Guidelines, vol. 5, ch. 3). A Tier 1 method is provided to estimated Variable 2B from Variable 1B.

HWP Variables 3, 4 and 5 (i.e., $P_{IM}$, $P_{EX}$, and H, respectively) are estimates of carbon in annual product imports and exports, as well as carbon in annual harvest for products and fuelwood. They are estimated on the basis of the forest products variables available in the FAO database.
Equation 12.1 (2006 Guidelines, vol. 4, ch.12) can be used to estimate the carbon stock changes in products in use (variable 1A and 2A) in *Solidwood products in use* and *Paper products in use*.
To estimate the carbon in annual consumption of solidwood or paper products that came from wood harvested in the reporting country, equation 12.2 (2006 Guidelines, vol. 4, ch.12) has to be applied by using the following data and parameters:

- FAO data to estimate product consumption (table 12.5, vol. 4, ch.12);
- default factors to convert solidwood and paper from volume units to carbon (table 12.4, vol. 4, ch.12);
- Half-lives for products in use (table 12.2, vol. 4, ch.12).

The carbon in annual production of solidwood or paper products that came from wood harvested in the reporting country can be estimated by using equation 12.3 (2006 Guidelines, vol. 4, ch.12), since it can be applied in case the country is a net importer of industrial roundwood (IRW), wood chips and wood residues used in HWP, but also if the country is a net export of IRW, chips, and residues. Also in this case, the same data sources and parameters can be applied (i.e. FAO data from 1961, default factors and half-lives for products in use as reported in tables 12.5, 12.4 and 12.2, respectively).
Tier 1 methods are provided to estimate annual change in carbon stock in SWDS in the reporting country (variables 1B and 2B). In particular, the carbon stock change of HWP from domestic consumption discarded to SWDS of the reporting country (variable 1B) is estimated directly by the Waste Sector Tier 1 methods and spreadsheets (vol. 5, ch. 3, Section 3.2.1.1 "Spreadsheet model" and Section 3.4). The variable 2B is estimated based on the portion of the variable 1B that is from domestic harvest, by multiplying by the fraction of wood carbon consumed in the country in the current year that came from domestic harvest (eq. 12.4, vol. 4, ch. 12).
Estimates of annual imports, exports and harvest for Variables $P_{IM}$, $P_{EX}$, and H are needed for the most recent years only (Annex Equations 12A.3 and 12A.4, vol. 4, ch.12). FAOSTAT data related to default import, export and harvest can be applied (table 12.5, vol. 4, ch.12). Factors to convert from cubic meters or air dry tonne of product are shown in Table 12.4.

***Tier 2 and 3***

Higher Tiers involve the use of country-specific data to estimate of annual carbon change in "products in use" and in SWDS, as:

- annual production, imports and exports by product types and wood species;
- factors to convert activity data to carbon;
- rate at which products are discarded from use (half-life);
- annual activity data and parameters for Waste Sector, including $DOC_f$, the fraction of wood and paper that decays in SWDS.

Models can be used in applying Tier 3 method, also using decay functions other than first order decay.

The annual release to the atmosphere from HWP can be estimated using the five abovementioned HWP variables, with the eq. 2.15 (vol.4, ch.12) both for estimate the carbon release from wood stocks and for the estimation of carbon release from wood harvested in the reporting country.

**Box 3.31** – *Improvements for Harvested Wood Products in the 2019 Refinement*

## SUGGESTIONS AND REMARKS FROM EXPERTS

### Improvements for Harvested Wood Products in the 2019 Refinement

In the 2019 Refinement, guidance for HWPs maintains the existing approaches covered in the 2006 IPCC Guidelines, while clarifying the application of different methodologies and system boundaries. Moreover, the Refinement updated the description of approaches and data sources for estimating the HWP carbon pool, also considering new relevant scientific information, as the relevant methodological information and parameters contained in IPCC KP Supplement (e.g. carbon conversion factors).

A clear guidance is provided to consider the areas relevant to harvested wood biomass:

1. wood products in use (i.e. wood utilised as a material);
2. wood biomass used for energy purposes;
3. wood biomass in solid waste disposal sites (SWDS).

A specific section (i.e. 12.1) provides an useful glossary to understand terms and definitions used in the estimation process of $CO_2$ emissions and removals from HWP. Furthermore the HWP available approaches have been described, defining a conceptual framework and system boundary for estimating emissions and removals arising from HWP. A decision tree has been included in the guidance to support the inventory compiler in the selection of the relevant tier method for estimating $CO_2$ emissions and removals from HWP, based on the available activity data at country level.

# 4 WASTE

## Overview

In the 2006 IPCC Guidelines, there were some changes in the structure and scope of the guidance for the Waste sector compared to the previous guidelines. Specifically, the sector is now structured with one new chapter on "**Waste generation, composition and management data**" and four subsequent chapters that mirror the reporting structure of the CRTs. In this regard, the following new categories and subcategories were introduced to ensure coverage of all major management practices: **Biological treatment of solid waste**, for the estimation of $CH_4$ and $N_2O$ emissions from composting and anaerobic digestion in biogas facilities; and **Open burning of waste**, with the provision of additional guidance also on $CH_4$ emissions from the incineration.

Throughout the sector, changes also occurred in default activity rates, emission factors and other values and parameters. One significant revision occurred to the methodology for $CH_4$ emissions from landfills: the previous Tier 1 method, based on the maximum potential release of methane in the year of placement, was replaced by a simple first order decay model that provides the option to use data available from the UN and other sources. This approach includes regional and country-specific defaults on waste generation, composition and management, and provides a consistent basis for estimating GHG emissions across all tiers. This ensures a more accurate time series for estimated emissions and should avoid the situation in which usage of landfill gas apparently exceeds the amount generated in a particular year. Moreover, carbon accumulation in landfills is provided as an output from the decay models, and can be relevant for the estimation of HWPs in AFOLU.

**Box 4.1** – *Summary of main improvements from the 1996 to the 2006 IPCC Guidelines for the Waste sector*

| **MAIN SPECIFIC IMPROVEMENTS ACROSS THE WASTE SECTOR** | |
|---|---|
| Added: | - New category: Biological treatment of solid waste;<br>- New subcategories: Open burning of waste, Uncategorized waste disposal sites. |
| Revised: | - Slight revision of the guidance structure;<br>- Revised methodology for methane emissions from landfills (first order decay method);<br>- Revised guidance on carbon accumulation in landfills, treatment and open burning of waste;<br>- Revised default activity rates, emission factors and parameters. |

## 4.1 Waste generation, composition and management data

The new chapter provides guidance on the compilation of activity data on waste generation, composition and management which represent the basis for the estimation of GHG emissions from solid waste disposal, biological treatment and incineration and open burning of waste.

For **waste generation and management data**, guidance is given on how to collect data on waste generation and management practices (for MSW, sludge, industrial and other waste). Specific tables with regional defaults on MSW generation and treatment data (Table 2.1) and with industrial waste generation in selected countries (Table 2.2) are also provided, as well as an annex with country and regional averages on MSW generation and management data (Annex 2A.1).

For **waste composition**, guidance is available for MSW, sludge, industrial and other waste, including regional defaults for MSW composition data (Table 2.3).

**Box 4.2** – *Waste generation, composition and management data in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Waste generation, composition and management data in the 2019 Refinement**

In the 2019 Refinement, some changes occurred to this chapter. Specifically:

- on waste generation and management data, refinements were made for MSW through the provision of updated and more disaggregated regional default values (Table 2.1) and through an updated and further disaggregated country and regional averages (Annex 2A.2);
- on waste composition, refinements were made for MSW through the provision of updated regional default values (Table 2.3) and via the addition of a new table including country and regional averages (Table 2A.2); and for sludge, through the update of the definition, updated guidance on DOC and a new table including default values and uncertainty of carbon content, nitrogen content and DOC of domestic and industrial sludge as percentage of dry matter (Table 2.4a).

## 4.2 Solid waste disposal (5.A)

### *4.2.1 Overarching changes*

In the 2006 IPCC Guidelines, some changes occurred for solid waste disposal categories. Specifically, default method for calculating emissions from Solid Waste Disposal Sites (SWDS) changed from "mass balance" to "first-order decay" (FOD), for which guidance was already given in IPCC 2000 Good Practice Guidance. Moreover, additional information and guidance for methane recovery was provided.

**Box 4.3** – *The First Order Decay (FOD) model*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**The First Order Decay (FOD) model**

The basis for a first order decay reaction is that the reaction rate is proportional to the amount of reactant remaining. The FOD model is built on an exponential factor that describes the degradable organic component in waste (degradable organic carbon, DOC) which each year is degraded into $CH_4$ and $CO_2$. Under constant conditions, the rate of $CH_4$ production depends solely on the amount of carbon remaining in the waste. Consequently, emissions of $CH_4$ are highest in the first few years after deposition, then gradually decline as the degradable carbon in the waste is consumed. Half-lives for different types of waste vary from a few years to several decades or longer, so the FOD method requires data to be collected or estimated for historical disposals of waste over a time period of 3 to 5 half-lives in order to achieve an acceptably accurate result. It is therefore good practice to use disposal data for at least 50 years as this time frame provides an acceptably accurate result for most typical disposal practices and conditions. The Guidelines provide guidance on how to estimate historical waste disposal data (Section 3.2.2, Choice of Activity Data), default values for all the parameters of the FOD model (Section 3.2.3, Choice of Emission Factors and Parameters), and a simple spreadsheet model to assist countries in using the FOD method.

The 2006 IPCC Guidelines also require the inclusion of certain industrial waste (agro-food industrial waste, pulp and paper waste and sludge, and waste from wood processing) and other non-MSW categories (construction and demolition wastes, and hazardous and clinical wastes which features new default values for DOC and fossil carbon content), which may introduce some challenges in the collection of activity data (quantities of each type of waste produced; quantities of waste sent to each type of treatment or disposal facility) since they now have to be considered along with municipal solid waste (MSW) under this category, despite not being usually handled with MSW.

Additionally, the following changes occurred to default emission factors and default parameters:

- New regional default data for Municipal Solid Waste (MSW) composition data.
- New default values for dry matter content, DOC content in % dry waste, total carbon content in % of dry weight and fossil carbon fraction in % of total carbon.
- New (nappies, rubber and leather, plastics, metal, glass, other inert waste) and updated (garden and park waste, wood) default values for DOC. These values could also be used for estimating carbon stored in SWDS (via FOD model). Carbon stored in SWDS is to be reported as an information item.
- Methane generation potential ($L_o$) is calculated from the amount of decomposable DOC in SWDS.
- Update and detailing of k-values (methane generation rate per type of waste) and of half-lives for FOD model (1996 IPCC Guidelines only provided range irrespective from waste type).
- Updated uncertainties associated with default data and parameters in the FOD method.

**Box 4.4** – *Solid waste disposal in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Solid waste disposal in the 2019 Refinement**

In the 2019 Refinement, key parameters in the first order decay (FOD) model were updated for waste composition and management (paragraph 3.2.1.1). Moreover, for the choice of emission factors and parameters, an update to the default values for DOCf (the fraction of degradable organic carbon that is dissimilated) was made including through the inclusion of new tables (paragraph 3.2.3): in particular, the 2019 Refinement has updated the default value (previously 0.5) for:

- Highly decomposable wastes (food, garden, sludge): 0.7
- Less decomposable wastes (wood): 0.1

In addition, the new guidelines introduce new classifications: the 2019 Refinement brings greater disaggregation of the 'managed, semi-aerobic' sites (5.A.1.b under the 2006 IPCC Guidelines) into those that are: i) managed well, and ii) poorly managed and an addition of a new classification for managed sites is given for 'active aeration'.

Finally, the 2019 Refinement provides updated guidance on uncertainties associated with parameters (section 3.7.2.2)

### *4.2.2 Managed waste disposal sites (5.A.1)*

In the 2006 IPCC Guidelines, specific improvements were made for default emission factors or default parameters pertaining managed waste disposal sites, namely:

- Update of country-specific data and default values for estimation of total municipal solid waste (MSW) generated and disposed in solid waste disposal sites (SWDS).
- New regional defaults for fractions: i) fraction of MSW incinerated, ii) fraction of MSW composted, iii) fraction of other MSW management, unspecified.
- Methane correction factor: type of site 'Managed' is now subdivided into 'Managed – aerobic' and 'Managed – Semi-aerobic' (2006 IPCC Guidelines, table 3.1).
- Newly introduced default values for DOC and fossil carbon content for process waste, i.e. industrial waste generated at the facilities (2006 IPCC Guidelines, table 2.5).
- Provision of an oxidation factor (OX) = '0.1' as default value for well-managed landfills, as in the 2000 IPCC Good Practice Guidance, while the 1996 IPCC Guidelines recommended the use of '0', as no internationally accepted default value could be provided.

### *4.2.3 Unmanaged waste disposal sites (5.A.2)*

Waste disposal practices vary in the control, placement of waste and management of the site. The $CH_4$ correction factor (MCF) accounts for the fact that unmanaged SWDS produce less $CH_4$ from a given amount of waste than anaerobic managed SWDS. In unmanaged SWDS, a larger fraction of waste decomposes aerobically in the top layer. In unmanaged SWDS with deep disposal and/or with high water table, the fraction of waste that degrades aerobically should be smaller than in shallow SWDS. An MCF is assigned to each of four categories (as shown in the 2006 IPCC Guidelines, Volume 5, Chapter 3, Table 3.1.A).

### *4.2.4 Uncategorized waste disposal sites (5.A.3)*

If countries cannot categorise their SWDS into one of the four categories of managed and unmanaged SWDS, it can be used the definition of "uncategorised SWDS" and the relevant MCF must be used.

### *4.2.5 Tabular summary of changes for Solid Waste Disposal*

**Table 4.1** – *Solid Waste Disposal: tabular summary of changes from the revised 1996 IPCC Guidelines to the 2006 IPCC Guidelines. (Highlighted in red are new categories/subcategories).*

| 1996 IPCC Guidelines | 2006 IPCC Guidelines |
|---|---|
| **6.A Solid Waste Disposal on Land** | **4.A Solid Waste Disposal** |
| **6.A.1 Managed Waste Disposal on Land** | **4.A.1 Managed Waste Disposal Sites** |
| **6.A.2 Unmanaged Waste Disposal Sites** | **4.A.2 Unmanaged Waste Disposal Sites** |
| **6.A.3 Other** | **4.A.3 Uncategorized Waste Disposal Sites** |

### *4.2.6 2006 IPCC categories in the CRTs (Solid Waste Disposal)*

**Table 4.2** – *Solid Waste Disposal: tabular summary of correspondence between categories and subcategories in the 2006 IPCC Guidelines and the reporting structure of UNFCCC's CRTs*

| 2006 IPCC Guidelines | CRTs (UNFCCC reporting) |
|---|---|
| **4.A Solid Waste Disposal** | **5.A Solid Waste Disposal** |
| **4.A.1 Managed Waste Disposal Sites** | **5.A.1 Managed Waste Disposal Sites** |
| | 5.A.1.a. Anaerobic *(child nodes can be added)* |
| | 5.A.1.b. Semi-aerobic *(child nodes can be added)* |
| | 5.A.1.c. Active-aeration *(child nodes can be added)* |
| **4.A.2 Unmanaged Waste Disposal Sites** | **5.A.2 Unmanaged Waste Disposal Sites** *(child nodes can be added)* |
| **4.A.3 Uncategorized Waste Disposal Sites** | 5.A.3 **Uncategorized Waste Disposal Sites** *(child nodes can be added)* |

## 4.3 Biological treatment of solid waste (5.B)

### *4.3.1 Overarching changes*

In the 2006 IPCC Guidelines, this new chapter provides guidance for the estimation of $CH_4$ and $N_2O$ emissions from composting, anaerobic digestion of organic waste and mechanical-biological treatment of waste, allowing for a more complete coverage of sources. The guidelines provide an indication of the steps needed to conduct the estimation: 1) collecting data on the amount and type of solid waste treated biologically; 2) estimating $CH_4$ and $N_2O$ emissions via specific equations and default or country-specific EFs; 3) calculating net emissions in case $CH_4$ emissions from anaerobic digestion are recovered.

### *4.3.2 Tabular summary of changes for Biological Treatment of Solid Waste*

**Table 4.3** – *Biological Treatment of Solid Waste: tabular summary of changes from the revised 1996 IPCC Guidelines to the 2006 IPCC Guidelines (this category is highlighted in red as it is a new category in the 2006 IPCC Guidelines).*

| 1996 IPCC Guidelines | 2006 IPCC Guidelines |
|---|---|
| | **4.B Biological Treatment of Solid Waste** |

### *4.3.3 2006 IPCC categories in the CRTs (Biological Treatment of Solid Waste)*

**Table 4.4** – *Biological Treatment of Solid Waste: tabular summary of correspondence between categories and subcategories in the 2006 IPCC Guidelines and the reporting structure of UNFCCC's CRTs.*

| 2006 IPCC Guidelines | CRTs (UNFCCC reporting) |
|---|---|
| **4.B Biological Treatment of Solid Waste** | **5.B Biological treatment of solid waste** |
| | **5.B.1 Composting** |
| | 5.B.1.a Municipal solid waste |
| | 5.B.1.b Other *(child nodes can be added)* |
| | 5.B.**2 Anaerobic digestion at biogas facilities** |
| | 5.B.2.a Municipal solid waste |
| | 5.B.2.b Other *(child nodes can be added)* |

## 4.4 Incineration and open burning of waste (5.C)

### *4.4.1 Overarching changes*

In the 2006 IPCC Guidelines, updated default emission factors for industrial waste and sewage sludge were included, as well as a new default emission factors for a new type of waste, namely "fossil liquid

waste", and new default emission factors for $CH_4$ emissions from incineration of MSW with different types of incineration provided.

**Box 4.5** – *Incineration and open burning of waste in the 2019 Refinement*

**SUGGESTIONS AND REMARKS FROM EXPERTS**

**Incineration and open burning of waste in the 2019 Refinement**

In the 2019 Refinement, the introduction section of incineration and open burning of waste chapter was updated and extensively integrated, especially through the inclusion of new definitions and boxes on processes for thermal technologies including pyrolysis, gasification and plasma. Where these activities are identified, waste inventory compilers will need to work closely with their energy sector counterparts. The gas products generated from these activities are usually collected and used mostly as fuels and chemical feedstocks. Direct emissions of $CH_4$ and $N_2O$ will be low unless intentionally vented. As with other biogas recovery mechanisms in the waste sector, emissions from the downstream burning of any gas products should be reported under the energy sector. Moreover, some values and guidance in the section pertaining to the choice of emissions factors were updated, including via the addition of new tables and boxes on processes.

### *4.4.2 Waste incineration (5.C.1)*

As illustrated in the Overview section of this module, specific Tier 1, Tier 2 and Tier 3 methodologies have been provided along with relevant tables, including an overview of data sources of different tier levels. Refined methods in the 2006 IPCC Guidelines require the consideration of dry matter content of waste. Moreover, new guidance for the calculation of $CH_4$ emissions is provided (in the 1996 IPCC Guidelines there were no detailed methodologies, while the 2000 IPCC Good Practice Guidance considered $CH_4$ emissions not likely to be significant).

### *4.4.3 Open burning of waste (5.C.2)*

In the 2006 IPCC Guidelines, an additional paragraph was added to provide guidance on the estimation of emissions from open burning of waste along with waste incineration, with specific examples and information provided to estimate activity data and default $CO_2$ and $N_2O$ emission factors.

### *4.4.4 Tabular summary of changes for Incineration and Open Burning of Waste*

**Table 4.5** – *Incineration and Open Burning of Waste: tabular summary of changes from the revised 1996 IPCC Guidelines to the 2006 IPCC Guidelines. (Highlighted in blue are disaggregated categories/subcategories).*

| 1996 IPCC Guidelines | 2006 IPCC Guidelines |
|---|---|
| | |
| **6.C Incineration and open burning of waste** | **4.C Incineration and open burning of waste** |
| | **4.C.1 Waste Incineration** |
| | **4.C.2 Open Burning of Waste** |

### *4.4.5 2006 IPCC categories in the CRTs (Incineration and Open Burning of Waste)*

**Table 4.6** – *Incineration and Open Burning of Waste: tabular summary of correspondence between categories and subcategories in the 2006 IPCC Guidelines and the reporting structure of UNFCCC's CRTs*

| 2006 IPCC Guidelines | CRTs (UNFCCC reporting) |
|---|---|
| | |
| **4.C Incineration and open burning of waste** | **5.C Incineration and open burning of waste** |
| **4.C.1 Waste Incineration** | **5.C.1 Waste incineration** |
| | **5.C.1.a Biogenic** |
| | 5.C.1.a.i Municipal solid waste |
| | 5.C.1.a.ii Other *(child nodes can be added)* |
| | **5.C.1.b Non-biogenic** |
| | 5.C.1.b.i Municipal solid waste |
| | 5.C.1.b.ii Other *(child nodes can be added)* |
| **4.C.2 Open Burning of Waste** | **5.C.2 Open burning of waste** |

| 2006 IPCC Guidelines | CRTs (UNFCCC reporting) |
|---|---|
| | **5.C.2.a Biogenic** |
| | 5.C.2.a.i Municipal solid waste |
| | 5.C.2.a.ii Other *(child nodes can be added)* |
| | **5.C.2.b Non-biogenic** |
| | 5.C.2.b.i Municipal solid waste |
| | 5.C.2.b.ii Other *(child nodes can be added)* |

## 4.5 Wastewater treatment and discharge (5.D)

### *4.5.1 Overarching changes*

In the 2006 IPCC Guidelines, it should be noted that there is no more distinction between emissions from wastewater and sludge (there used to be separate equations in the 1996 IPCC Guidelines). However, sludge should be separated as subcategory if appropriate data is available.
Moreover, the 2006 IPCC Guidelines included methods to estimate $CH_4$ and $N_2O$ emissions from septic tanks and latrines, as well as from discharge of wastewater into waterways. Specifically, for the estimation of $N_2O$ emissions from wastewater, direct emissions from treatment plants and indirect emissions from wastewater after disposal effluent into aquatic environments are now considered. Moreover, there are additional fractions for the calculation of total amount of nitrogen in the wastewater effluent, with one factor for non-consumed protein, and one factor for industrial and commercial co-discharged protein and nitrogen removed with sludge.
The 2006 IPCC Guidelines also provide improved default emission factors and default parameters, including:

- New values of urbanization for different countries.
- Introduction of the degree of utilisation of treatment/discharge pathway or system.
- Update of maximum $CH_4$ producing potential ($B_o$).
- Update of $BOD_5$ values for regions "Canada, Europe, Russia, Oceania", and additionally new values for individual countries.
- Expansion of default MCF for different systems.
- New uncertainty ranges for domestic wastewater and industrial wastewater.

**Box 4.6** – *Wastewater treatment and discharge in the 2019 Refinement*

***Suggestions and remarks from experts***

**Wastewater treatment and discharge in the 2019 Refinement**
The 2019 Refinement introduced some changes for wastewater treatment and discharge. In the introduction section, updated guidance including a revised chart for wastewater treatment systems and discharge pathways is available. New paragraphs on "centralised wastewater treatment systems", "decentralised treatment systems of domestic wastewater" and "emissions from receiving waters" were also added. Moreover, revised guidance, tables and decision trees for domestic wastewater and industrial wastewater were made available, as the combined equations to estimate $CH_4$ emissions from wastewater and from sludge removed from the wastewater, with the consequence that the use of a default value of zero for sludge removal from aerobic treatment systems and septic systems is no longer applicable. In addition, similar improvements were made for the section dealing with nitrous oxide emissions from wastewater, which in the 2019 Refinement are disaggregated into domestic (section 6.3) and industrial (section 6.4). Certain emission factors for $CH_4$ and $N_2O$ emissions from wastewater after disposal of untreated wastewater or wastewater treatment effluent into aquatic environments were also updated, to reflect additional measurement data. Finally, non-biogenic (fossil) $CO_2$ emissions from wastewater treatment and discharge are considered in an Appendix (6A.1) as basis for future methodological development.

### *4.5.2 Domestic wastewater treatment and discharge (5.D.1)*

Methods have been refined with a new distinction of different income groups (rural, urban high income and urban low income) for the estimation of $CH_4$ emissions from domestic wastewater.

### *4.5.3 Industrial wastewater treatment and discharge (5.D.2)*

The following methods have been refined:

- New guidance for the estimation of $CH_4$ emissions from uncollected wastewater and $N_2O$ emissions from advanced wastewater treatment plants.
- Simplification of industrial wastewater (only most significant industrial sources need to be considered).
- New guidance for emissions from advanced centralised wastewater treatment plants (especially for countries with plants with controlled nitrification and denitrification steps).

### *4.5.4 Tabular summary of changes for Wastewater Treatment and Discharge*

**Table 4.7** – *Wastewater Treatment and Discharge: tabular summary of changes from the revised 1996 IPCC Guidelines to the 2006 IPCC Guidelines.*

| 1996 IPCC Guidelines | 2006 IPCC Guidelines |
|---|---|
| | |
| **6.B Wastewater water Handling** | **4.D Wastewater Treatment and Discharge** |
| **6.B.1 Domestic and Commercial Wastewater** | **4.D.1 Domestic Wastewater Treatment and Discharge** |
| **6.B.2 Industrial Waste water** | **4.D.2 Industrial Wastewater Treatment and Discharge** |
| **6.B.3 Other** | |

### *4.5.5 2006 IPCC categories in the CRTs (Wastewater Treatment and Discharge)*

**Table 4.8** – *Wastewater Treatment and Discharge: tabular summary of correspondence between categories and subcategories in the 2006 IPCC Guidelines and the reporting structure of UNFCCC's CRTs.*

| 2006 IPCC Guidelines | CRTs (UNFCCC reporting) |
|---|---|
| | |
| **4.D Wastewater Treatment and Discharge** | **5.D Wastewater Treatment and Discharge** |
| **4.D.1 Domestic Wastewater Treatment and Discharge** | **5.D.1 Domestic wastewater** |
| **4.D.2 Industrial Wastewater Treatment and Discharge** | **5.D.2 Industrial wastewater** |
| | **5.D.3 Other** |

# REFERENCES


ICAT (website). “Country activities”. Online: https://climateactiontransparency.org/country-activities/

IPCC (2003). Good Practice Guidance for Land Use, Land-Use Change and Forestry. IPCC Technical Support Unit, Kanagawa, Japan.

IPCC (2006). Guidelines for National Greenhouse Gas Inventories. IPCC Technical Support Unit, Kanagawa, Japan.

IPCC (2014). 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol, Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M. and Troxler, T.G. (eds) Published: IPCC, Switzerland.

IPCC 2019, 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Calvo Buendia, E., Tanabe, K., Kranjc, A., Baasansuren, J., Fukuda, M., Ngarize, S., Osako, A., Pyrozhenko, Y., Shermanau, P. and Federici, S. (eds). Published: IPCC, Switzerland.

UNFCCC (2010). Decision 1/CP.16. The Cancun Agreements: “Outcome of the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention”. Online: https://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf

UNFCCC (2011). Decision 2/CP.17. “UNFCCC biennial update reporting guidelines for Parties not included in Annex I to the Convention”. Online: https://unfccc.int/sites/default/files/resource/docs/2011/cop17/eng/09a01.pdf#page=39

UNFCCC (2011). Decision 2/CP.17. “UNFCCC biennial reporting guidelines for developed country Parties”. Online: https://unfccc.int/sites/default/files/resource/docs/2011/cop17/eng/09a01.pdf#page=31

UNFCCC (2012). Decision 19/CP.18. “Common tabular format for “UNFCCC biennial reporting guidelines for developed country Parties”. Online: https://unfccc.int/resource/docs/2012/cop18/eng/08a03.pdf

UNFCCC (2018). Decision 18/CMA.1. “Modalities, procedures and guidelines for the transparency framework for action and support referred to in Article 13 of the Paris Agreement”. Online: https://unfccc.int/sites/default/files/resource/cma2018_3_add2_new_advance.pdf#page=18

UNFCCC (2018). Decision 1/CP.24. “Preparations for the implementation of the Paris Agreement and the first session of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement”. Online: https://unfccc.int/sites/default/files/resource/10a1.pdf#page=2

UNFCCC (2019). Decision 6/CP.25. “Revision of the UNFCCC reporting guidelines on national communications for Parties included in Annex I to the Convention”. Online: https://unfccc.int/sites/default/files/resource/cp2019_13a01_adv.pdf#page=28

UNFCCC (2021). Decision 5/CMA.3. “Guidance for operationalizing the modalities, procedures and guidelines for the enhanced transparency framework referred to in Article 13 of the Paris Agreement”. Online: https://unfccc.int/sites/default/files/resource/cma3_auv_5_transparency_0.pdf

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