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Horizon 2020 Societal challenge 5:
Climate action, environment, resource efficiency and raw materials

VERIFY

Observation-based system for monitoring and verification of greenhouse gases

GA number 776810, RIA

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1. Changes with respect to the DoA

None.

2. Dissemination and uptake

(Who will/could use this deliverable, within the project or outside the project?)

The material presented in this deliverable is of primary interest to all partners of the VERIFY consortium and it should also be distributed outside the project, especially to stakeholders.

3. Short Summary of results (<250 words)

Science plays a crucial role in the UNFCCC framework, providing data and methods for GHG estimations and, in the view of the Paris Agreement (PA) implementation, serving as "benchmark" for assessing the collective achievement of the 2°C temperature goal, within the Global Stocktake process.
On the other hand, the emissions resulting from GHG inventories (GHGIs) provided by Parties under the UNFCCC and the results from the climate science may be not directly comparable as there are intrinsic differences in scope that should be carefully considered.
The aim of this deliverable is to explore issues linked to terminology and definition within each inventory sector to build a common understanding of the main differences that should lead to a common language to bridge the two communities.
The analysis involved directly the inventory agencies within VERIFY, showing that the main terminological issues are related to the Land Use, Land-Use Change and Forestry (LULUCF) sector while the other sectors have signaled issues that are more generally linked to different approaches in use between the GHGIs and the climate science such as: system boundaries, temporal and spatial scale, methodologies, emission attribution etc.
To create a common ground for science and inventory frameworks, the deliverable provides the key concepts, terms and approaches in use within the general UNFCCC reporting framework, with an overview of comparability issues between the climate science and GHGIs as reported by the Inventory agencies. The analysis of the terminology problems is provided in details for the LULUCF sector, which was the sector that mostly reported problems linked to the different terms in use. In addition, to increase the understanding of the inventory framework, the main inventory methods and approaches are reported for each sector, describing the main terms in use.

4. Evidence of accomplishment

(report, manuscript, web-link, other)

The content of this report represents the accomplishment of the work.

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1. Introduction

Reporting of Greenhouse Gas (GHG) emissions under the United Nations Framework Convention on Climate Change (UNFCCC) is based on the provision of transparent, accurate, complete, consistent and comparable GHG estimations through national inventories, which are essential links between science and policy-making. The quality and reliability of GHG inventories rely on the integrity of the science underpinning the methodologies, the completeness of sources and sinks, pools and gases within reporting and fulfillment of requirements for compilation of data. To achieve the provision of reliable and consistent GHG information, the Conference of the Parties (COP) has established a set of requirements for reporting national GHG inventories[1] to be fulfilled in accordance with Intergovernmental Panel on Climate Change (IPCC) guidelines[2] and guidance.

The Paris Agreement (PA) includes an enhanced transparency framework, to track countries' progress towards achieving their individual targets (i.e. the nationally determined contributions, NDC) and a Global Stocktake (every five years starting 2023) to assess the countries collective progress towards the long term goals of the PA based on the best available science. Thus the Global Stocktake shall assess whether the "collective progress" resulting by the sum of the GHG inventories from Parties is in line with the "well-below 2°C trajectory" as defined in the IPCC Assessment Report (AR), thus produced from atmospheric observation and models by the climate scientific community. Any identified gaps should result in an increased mitigation ambition by countries in successive rounds of NDCs. As consequence, climate science is playing a crucial role in the UNFCCC framework, providing data and methods for GHG estimations on the global level and, in the view of the PA implementation, also as "benchmark" for assessing the achievement of the 2°C temperature goal.

On the other hand, the emissions resulting from GHG inventories (GHGIs) under the UNFCCC and the results from and atmospheric observation and land/ocean models, i.e. IPCC AR, may be not directly comparable as there are intrinsic differences in scope that should be carefully considered:

[1] Report of the COP on its nineteenth session, held in Warsaw from 11 to 23 November 2013. Addendum: Decision 24/CP.19 on the Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention.

[2] IPCC. (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories (N. G. G. I. Programme, E. H.S., B. L., M. K., N. T.,& T. K Eds.). Japan: IGES.

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- The UNFCCC reporting Guidelines and hence the IPCC Guidelines (GLs) 2006 focuses on internationally agreed methodologies for the estimation of national anthropogenic GHG emissions by sources and reductions by sinks, and should result in a report with a consistent time-series data, and recognizing national circumstances, including technical capabilities;
- AR5 focuses on assessing the state of the science on the global carbon budget using globally applied data, definitions and modelling methods;
- Other climate change related studies focus on publishing new methodologies and results.

As GHG Inventory/reporting and the climate scientific communities may use different terminology and definitions within each sectors and methods in use, the aim of this deliverable is to build a common understanding of the main differences that should lead to a common language to bridge the two communities and create the basis for the identification of harmonized definitions and increase mutual understanding.

The terminology analysis is also aimed to inform the database that will be established under VERIFY, to guarantee that consistent terminology is applied and data is provided using the appropriate reporting definitions as to facilitate its use from inventory agencies.

To fulfill this task a questionnaire was distributed to the inventory agencies involved in WP1 (see box 1).

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BOX 1: Questionnaire distributed to WP1 inventory agencies

1. Do you think that, considering your sector, there is a problem linked to the terminology used in national GHG inventory reporting (UNFCCC) and independent research (as IPCC AR5)?

   If so, please, list them and briefly explain which are the corresponding interpretation/definition problems. Add citations if a specific terminological problem has already been considered and touched upon.

2. Do you think that, considering your sector, the application of different terminologies can (significantly) affect the comparison of the results estimated by national reporting (UNFCCC) and independent research (such as IPCC AR5)?

   If so, try to explain it briefly. Add citations if a specific terminological problem has just been considered and touch upon.

3. Would you suggest any solution to the issues above?

   Please provide the solution you think would be workable (if any), or provide any reference you think could be useful to find possible solution.

4. Are there other issues that you would like to bring to the attention to the scientific community in relation to the definition issue?

From the replies to the questionnaire it appeared evident that the main terminological issues are related to the Land Use, Land-Use Change and Forestry (LULUCF) sector, while the other sectors have signaled issues that are more generally linked to different approaches in use between the GHGIs and climate science such as: system boundaries, temporal and spatial scale, methodologies, emission attribution etc.

Overall, the inventory agencies have highlighted the importance of creating a common understanding on the inventory needs and terms in use. Thus, the deliverable attempts to clarify the main terminology and approaches within the reporting framework in general (section 2), focusing on the key concepts and terms used in the GHG Inventory framework. Section 3 provides an overview of the comparability issues between the climate science and GHGIs as reported by the inventory agencies. Section 4 focuses on the terminology issues in the LULUCF sector, which was the sector that mostly reported problems linked to the different terminology in use. To increase the understanding of the inventory framework, section 5 reports the main inventory methods and approaches for each sector, describing the main terms in use. Final considerations of the study are included in Section 6.

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2. Reporting Framework

Within the UNFCCC, GHG emissions trends are tracked through reporting obligations based on the provision of transparent, accurate, complete, consistent and comparable GHG estimations through national inventories, which are essential links between science and policy-making.

The data reported are then used for the accounting, i.e. the process to track the ability to achieve the target of emission reduction that a Party may have, e.g. under the Kyoto Protocol or, in the next future, under the PA, as defined in their NDC. Thus, accounting in the UNFCCC context has a very defined meaning, referring to the way the reported information is used to assess compliance with commitments, thus measuring the alteration of the emissions trends.

Developed country Parties (enlisted in the Annex I of the Convention) have the obligation of transmitting annually a GHG inventory including a National Inventory Report (15 reports 2003-2018), to provide every 4 years a National communication (reporting, inter alia, on policies and measures) and every 2 years a Biennial Report focusing mainly on the progress towards their 2020 target. National Inventory Reports (NIR) provide also information on accounting under the Kyoto Protocol. All these reports are subject to a review process (decision 19/CP.8) coordinated by the Secretariat.

Developing countries (non-Annex I) provide voluntarily their National Communication every 4 years, which include also GHG inventory with a Biennial Update Report (BUR), submitted every 2 years, consistent with the Party's capabilities or level of support provided. Verification of reports is addressed at the international level through the process of International Consultation and Analysis (ICA) of BURs. This is to identify support needed and received in order to increase the transparency of mitigation actions and their effects.

Under the PA, an enhanced transparency framework is established (art.13) with the purpose to provide a clear understanding of climate change action in the light of the objective of the PA through national inventory reports of their anthropogenic emissions and removals, and tracking the progress in achieving the NDC. The modalities and procedure for the framework are currently under development within the Paris Agreement Rulebook negotiations.

Currently, in preparing their inventory reports under the UNFCCC obligations, Annex I Country Parties shall follow the 2006 IPCC GLs for National Greenhouse Gas Inventories (2006 GLs), while the non-Annex I Parties still follow the Revised 1996 GLs, with some applying voluntarily the 2006 GLs.

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2.1. Key concepts and terms used in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

2006 IPCC GL are based on a set of concepts and definitions that are aimed at ensuring that inventories are comparable between countries, do not contain double counting or omissions, and that the time series reflect actual changes in emissions. We here provide the list of the fundamental concepts and definitions on which are based the reporting at country level:

Anthropogenic emissions and removals: only human induced emissions/removals have to be included in the inventories. The distinction between natural and anthropogenic emissions and removals follows straightforwardly from the data used to quantify human activity.

National territory: only greenhouse gas emissions and removals taking place within the national territory and offshore areas over which the country has jurisdiction have to be considered in the national inventories.

Inventory year: inventories have to consider estimates for the calendar year which the emissions to and removals from occur.

Time series: a sequence of annual GHGI estimates from the base year (e.g. 1990) and the year of submission minus 2 (e.g. in 2018 the time series will be from 1990 to 2016).

Sectors and Categories: GHG emission and removal estimates are strictly based on sources and sinks. These are divided into main sectors, which are groupings of related processes, sources and sinks:

- Energy;
- Industrial Processes and Product Use (IPPU);
- Agriculture, Forestry and Other Land Use (AFOLU);
- Waste;
- Other (e.g., indirect emissions from nitrogen deposition from non-agriculture sources).

Each sector comprises individual categories (e.g., transport) and sub-categories (e.g., cars). Ultimately, countries will construct an inventory from the sub-category level because this is how IPCC methodologies are set out, and total emissions calculated by summation. A national total is calculated by summing up emissions and removals for each gas. An exception is emissions from fuel use in ships and aircraft engaged in international transport which is not included in national totals, but is reported separately.

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Greenhouse gases considered: The UNFCCC Reporting GL consider the following greenhouse gas (GHG) list:

- carbon dioxide (CO_2);
- methane (CH_4);
- nitrous oxide (N_2O);
- hydrofluorocarbons (HFCs);
- perfluorocarbons (PFCs);
- sulphur hexafluoride (SF_6);
- nitrogen trifluoride (NF_3);
- trifluoromethyl sulphur pentafluoride (SF_5CF_3);
- halogenated ethers (e.g., $C_4F_9OC_2H_5$, $CHF_2OCF_2OC_2F_4OCHF_2$, $CHF_2OCF_2OCHF_2$);
- and other halocarbons not covered by the Montreal Protocol including CF_3I, $CH_2Br_2CHCl_3$, CH_3Cl, CH_2Cl_2.

The gases listed above have **global warming potentials (GWPs)** identified by the IPCC Assessment reports (most recent GWP use are the ones of the 4th AR). A GWP compares the radiative forcing of a tone of a greenhouse gas over a given time period (e.g., 100 years) to a tone of CO_2. The 2006 GLs also provide methods for gases for which GWP values were not available prior to finalization, i.e., $C_3F_7C(O)C_2F_5$, C_7F_{16}, C_4F_6, C_5F_8 and c-C_4F_8O. These gases are sometimes used as substitutes for gases that are included in the inventory and countries are encouraged to provide estimates for them.

The 2006 IPCC GLs also provide information for the reporting of the following precursors: nitrogen oxides (NOx), ammonia (NH_3), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO) and sulphur dioxide (SO_2) although methods for estimating emissions of these gases are not given here.

Basic methodological approach: IPCC GLs emission estimates are based on the simplest methodological approach, which combine the information on the extent to which a human activity take place (i.e. activity data - AD) with coefficients which quantify the emissions or removals per unit of activity data (i.e. emission factors - EF):

$$\text{Emissions} = \text{AD} \cdot \text{EF}$$

However, more complex modelling approaches are also allowed and regularly needed, especially at higher tier complexity level.

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Tiers: a tier represents a level of methodological complexity. Usually three tiers are provided. Tier 1 is the basic method, Tier 2 intermediate and Tier 3 most demanding in terms of complexity and data requirements (mostly plant specific data). Tiers 2 and 3 are sometimes referred to as higher tier methods and are generally considered to be more accurate.

Default data: Tier 1 methods for all categories are designed to use readily available national or international statistics in combination with the provided default emission factors and additional parameters that are provided, and therefore should be feasible for all countries.

Key Categories: the concept of key category is used to identify the categories that have a significant influence on a country's total inventory of greenhouse gases in terms of the absolute level of emissions and removals, the trend in emissions and removals, or uncertainty in emissions and removals. Key Categories should be the priority for countries during inventory resource allocation for data collection, compilation, quality assurance/quality control and reporting.

Uncertainty analysis: The 2006 IPCC GLs (IPCC, 2006a) defines uncertainties as "the lack of knowledge of the true value of a variable that can be described as a probability density function (PDF) characterizing the range and likelihood of possible values". Uncertainty depends on the analyst's state of knowledge, which in turn depends on the quality and quantity of applicable data as well as knowledge of underlying processes and inference methods.

The assessment and analysis of uncertainties of emission and removals are an essential element of GHGI. The IPCC Guidelines requests to derive uncertainty estimates for both the national level and the trend estimate, as well as for the component parts, i.e. emission factors, activity data and other estimation parameters for each category.

The analysis of uncertainties of GHG inventories is seen, as a mean to prioritize national efforts to reduce the uncertainty of inventories in the future, and guide decisions on methodological choice and therewith increase the overall quality of emission inventories. Hence, "the methods used to attribute uncertainty values must be practical, scientifically defensible, robust enough to be applicable to a range of categories of emissions by source and removals by sinks, methods and national circumstances, and presented in ways comprehensible to inventory users." (IPCC, 2006a).

The quantitative uncertainty analysis is performed by estimating the 95 percent confidence interval of the emissions and removals estimates for individual categories and for the total inventory.

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Confidence Interval: The true value of the quantity for which the interval is to be estimated is a fixed but unknown constant, such as the annual total emissions in a given year for a given country. The confidence interval is a range that encloses the true value of this unknown fixed quantity with a specified confidence (probability). Typically, a 95 percent confidence interval is used in greenhouse gas inventories. From a traditional statistical perspective, the 95 percent confidence interval has a 95 percent probability of enclosing the true but unknown value of the quantity. An alternative interpretation is that the confidence interval is a range that may safely be declared to be consistent with observed data or information. The 95 percent confidence interval is enclosed by the 2.5th and 97.5th percentiles of the PDF (IPCC, 2006b).

3. Comparability issues between GHG inventories and climate science

The Paris Agreement poses new challenges to the scientific world through the Global Stocktake process. The rules and procedures for the process are still under discussion within the PA, however there is a common understanding that the aggregated GHGIs will be compared with the emission pathways produced by the scientific world and synthetized by the IPCC within the assessment report. On the other side, the comparison with climate science research is also useful for the verification of the GHGI results, helping to assess the reliability of the process and to increase the confidence on the estimations. Thus an increased comparability between the two datasets is essential, although not always straightforward. Discrepancies between the datasets could have different sources, which may vary among sectors, scale of the assessment (from local to global) and time boundaries, such as those listed below.

3.1. System boundaries differences

Generally, climate science projects and GHGIs differ both for spatial and temporal scales.

- Considering the *spatial scale*, GHGIs (which are based on a bottom-up approach) specifically focus on country level, while top-down approaches are generally based on continental or global level with more or less high horizontal resolution (see Bergamaschi et al., 2005; Ciais et al., 2015; Konovalov et al., 2016; Saunois et al., 2016). In other cases, research studies are based on local scale projects. Therefore, the results of climate science research projects may not be compatible with the geographic scope of the inventory.
- Considering the *temporal scale*, GHGIs are based on yearly reports while top-down atmospheric approaches are based on a variable temporal scale but generally more refined (from monthly to few hours in specific cases, according to Ciais et al. (2015)) than

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that of the GHGIs. It means that, sometimes, results from climate science research projects may be relatively uncertain when aggregated in terms of total annual emissions (because of unknown temporal error correlations).

Estimating GHG fluxes of specific gases (like CH_4 and N_2O) at a finer spatial and temporal resolution by a top-down approach seem particularly relevant because these gases are predominately of microbial origin and, therefore, characterized by high spatial and temporal variability (Leip et al., 2018). Other sources characterized by high temporal variability are also represented by the Industrial Processes and Product Use (IPPU) sector, where process emissions may vary depending on the operating times and load of installations (e.g. emissions from the chemical industry), and emissions from product use may vary over the year (e.g. more emissions of refrigerants due to operation of air conditioners in summer).

It is important to note that the concept of total annual emissions is sufficient for the purpose of tracking GHG emissions under the UNFCCC. As the most relevant GHGs have lifetimes of decades to centuries, their total annual emissions (or even total cumulative emissions over longer periods) are of interest, rather than the exact point in time of these emissions. This situation is genuinely different for short-lived air pollutants, whose effects are often local/regional and for which both the time and the location of emissions are critical.

3.2. Methodology differences

GHGIs make wide use of emission factors, a concept which is not that widespread in climate science that uses approaches based on the inversion of atmospheric GHG concentration gradients in combination with more process-based flux models. Emission factors are not only used in low-tier approaches, but also in more complex approaches, when plant-specific or fuel-specific emission factors are used. Methodological differences do not only lead to difference in the mean estimates but also in the related uncertainties.

It is worth noticing that the uncertainty of an emission factor approach may be smaller than the uncertainty of emission measurements. For example, in the case of IPPUs, there is a greater variability in emission measurements due to products derived from industrial production (which depend on operating conditions and operation) rather than in the estimation of the resulting CO_2 emissions, which can be estimated with high accuracy, provided that the chemical composition of the inputs and outputs of the process is known.

Other discrepancies in methodological estimation between GHGIs and climate science research could be based on:

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- The consideration of *indirect emissions* (in GHGIs) or not (generally in climate science research), especially in IPPU. In this sector, the use of solvents and other products results in emissions of non-methane volatile organic compounds (NMVOC). As these are converted to CO_2 in the atmosphere, they are known as “precursors” or “indirect emissions” and are reported in GHG inventories. It has to be noted that these amounts of CO_2 may not be captured by independent monitoring of emissions, but they will be accounted for by the inversion of atmospheric CO_2 concentration gradients.
- The consideration of *emissions/removals from sources that are considered as significant* may change from top-down approaches and the GHGIs.
- The GHGIs application of methodologies may not fully reflect the real GHG emission from a specific category. A similar case was observed in Bergamaschi et al. (2005) for German CH_4 emission, where it was detected a gap of 30% of CH_4 emissions estimation from manure between direct top-down measurement and the bottom up approaches.

3.3. Emission attribution problems

On the basis of 2006 IPCC GLs, in the inventory preparation a distinction is made among emissions from each specific sector and each specific category. However, such a distinction may not be symmetrical in climate science research projects. For example, considering IPPU and Energy sector, it may be very difficult to estimate emission derived from energy and non-energy use of fuels/feedstock (e.g. in the chemical or iron and steel industry). In order to allow for independent verification, at least in this specific case, the emissions from the various categories have to be taken into account and summed up. Another example is the systematic distinction of a specific plant (e.g. steel plant or a refinery) in different source categories in the inventory within a sector.

3.4. Terminology

Different interpretation of the same terms in the two frameworks that may change the scope covered in the estimations (e.g. definition of anthropogenic sources or sinks in a forest) or lack of sufficient detailed information to understand the scope of the estimation (e.g. definition of grassland that may comprise various land covers). According to this analysis, the Land Use, Land-Use Change and Forestry (LULUCF) sector seems to be the one that is mostly affected by issues related to terminology in use. It is plausible that it is due to the fact that, among all the others, it is characterised by the interaction of two important aspects:

- the highest level of complexity in GHG pathways
- Difficulties to differentiate the anthropogenic and non-anthropogenic fluxes
- Methodological complexity

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According to Pulles (2018), a measure of the methodological complexity of the Agriculture, Forestry and Other Land Use (AFOLU) sector (e.g. LULUCF + Agriculture) in comparison with the other sectors is provided by the significant larger amount of both number of pages in the 2006 IPCC GLs and the higher number of pages in the worksheets with respect to other sectors (Figure 1).

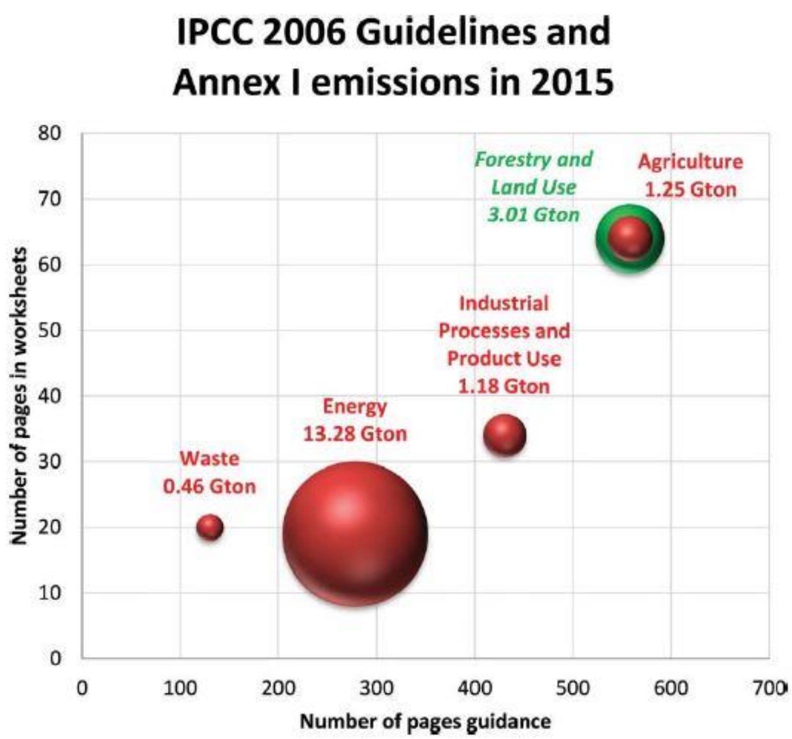

Figure 1: Size (in pages) of sectoral volumes of IPCC 200 GLs (the horizontal axis shows the guidance chapters; the vertical axis shows the worksheet descriptions). The size of the circles reflects the absolute emissions (in red) or removals (in green) of each sector in 2015 are reported by the 44 Annex I Parties in 2017. Image source: Pulles (2018).

4. Terminological issues in the land use, land-use change and forestry (LULUCF) sector

4.1. Brief introduction on reporting GL.

In LULUCF sector GHG emissions and removals by inland ecosystems caused by anthropogenic activities have to estimate and report. According to IPCC GL (2006b), anthropogenic GHG emission and removals are defined as all those occurring on “managed land”. For the inventory purpose, the land area can be categorised in six land uses (Forest Land, Cropland, Grassland, Wetlands, Settlements and Other Land) and in turn in land management systems. In addition, each land use category can be subdivided into land remaining in that category and land converted from one category to another. For each land use and all the possible transitions, three aggregate carbon pools have to be considered in addition to (whenever necessary) harvested woody products (HWP):

- Biomass (living): above and belowground;
- Dead organic matter: litter and deadwood;
- Soil organic carbon: in mineral and organic soils.

The GHGs considered under the LULUCF sector are CO_2, CH_4, N_2O, NOx, CO and NMVOC (i.e. non-methane volatile organic compound).

4.2. Terminological issues

LULUCF sector is characterized by many issues related to terminology used in national GHG inventory reporting (UNFCCC) and climate science research, as listed below.

Anthropogenic effects are differently defined under IPCC GLs (2006b) for GHG Reporting under UNFCCC and climate science (as AR5). In the first case they are considered as all the effects caused by the land management (IPCC *managed land proxy*), that is all the emissions/removals derived by a *land where human interventions and practices have been applied to perform production, ecological or social functions* (IPCC 2006b). On opposite, research generally does not consider all the processes on managed lands as anthropogenic sources/sinks. For example, IPCC AR5 (Ciais et al. 2013, Smith et al. 2014) does not consider C stock changes due to CO_2 fertilizations and N deposition as part of anthropogenic effects and, therefore, it considers them as part of the “terrestrial residual sink” (Grassi et al., 2017; Federici et al., 2017). *Therefore, the main difference is that IPCC AR5 considers only direct human-induced activities (i.e. changes in vegetation distribution), while IPCC Guidelines take into account all emissions and removal*

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occurring on managed land, thus including both direct and indirect ones (Pongratz et al., 2014; Grassi et al., 2017; Federici et al., 2017).

Managed land. Even if it is defined under IPCC GLs (2006b) [see *Anthropogenic effects*], this definition is not prescriptive and, therefore, countries are encouraged to specify it according to their specific circumstances (Grassi et al., 2017; Federici et al., 2017). Therefore, any managed land emissions comparison among countries can be significantly affected by different definitions of management.

Land Use (LU) and land cover (LC) definitions. Land use is an expression used to describe the human use and management of the soil cover. Although the IPCC GLs call for land use definitions, scientific studies are usually based on the remotely sensed data elaboration that takes into account biophysical characteristics of the terrestrial surface (i.e. *land cover* typologies) (Federici et al., 2017). For example, it means that, on one side, the satellite data are able to detect a change in the land cover over a harvested forest while a no real land use change occurs and, on the other side, that satellite data are not able to identify any specific change in management practices in agricultural lands (cropland). This issue has an inevitably effect on the estimations comparison among national reporting and scientific elaborations. In addition, Federici et al. (2017) and many other authors highlighted that the LU definition can differ among international organisations and countries. Indeed, the 2006 IPCC GLs give the possibility to each party to adopt a specific definition of IPCC land use categories which may or may not refer to the internationally accepted ones (as for example those of FAO Ramsar, etc.), provided that it will be applied consistently.

Forest definitions are generally based on a list of parameters (e.g. minimum area, minimum plants height at maturity, etc…) which can differ among international organizations (e.g. FAO, UNFCCC, etc.) and countries (see

Table 1), and among different scientific researches (see Table 2) (Federici et al., 2017). In addition, the same authors suggested that some types of tree cover (like rubber tree plantations) can be excluded by forest definition as a function of the definition adopted by the country. These differences can affect forest-related emission/removal estimations (Grassi et al., 2017).

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Table 1. Comparison between UNFCCC and FRA parameter threshold used for the definition of forest. Table source: Federici et al. (2017).

Parameter	UNFCCC	FRA
Minimum area	0.05-1.0 ha	0.5 ha
Minimum height	2-5 m	5 m
Minimum crown cover	10-30%	10%
Minimum time since conversion	Not available	~10 years
Minimum strip width	Not available	20 m
Other parameters covered in definition	Young stands, temporarily unstocked areas	Young stands, temporarily unstocked areas, predominant land use agroforestry

Table 2. Comparison among the forest definition adopted by a few scientific studies. Table source: Federici et al. (2017).

Study	Forest definition
Achard at al (2014)	Forests are stratified into 3 classes: i) >70% crown cover, ii) 30% to 70% crown cover, iii) other woody vegetation
Baccini et al (2012)	FAO (by implication)
Federici et al (2015)	FAO
Hansen et al (2013)	Tree cover over 5m height at various crown cover thresholds at the Landsat pixel scale (.09 ha)
Harris et al (2012a)	Forest cover is defined as 25% or greater canopy closure at the Landsat pixel scale (.09 ha) for trees >5 m in height. Includes intact forests, plantations, or forest regrowth. Deforestation is defined as the reduction of canopy cover to below this 25% threshold
Pan et al (2011)	FAO (including temporarily unstocked areas and plantations)
Saatchi et al (2011)	>10% tree cover as defined by the MODIS vegetation continuous field product
Tyukavina et al (2015)	Any vegetation taller than 5m with canopy cover ⩾25% (both natural forests and plantations)

Grassland is a wide category, which, according to IPCC GL (2006c), can include different vegetation types (e.g. open savannas, scrubland, pasture, etc.) and different degree and intensity of management. Grassland definition is strictly linked to those used for forest and cropland categories. In the IPCC GL (2006b) *grassland 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.*

Thus in IPCC GLs Grasslands are generally distinguished from "forest" as ecosystems having a tree canopy cover of less than a certain threshold, which varies from country to country [see *Forest* section]. Many shrublands with high proportions of perennial woody biomass may be considered to be a type of grassland and countries may elect to account for some or all of these shrub lands in the Grassland category (IPCC GLs, 2006c). On the other hand, the various

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grassland definitions used in scientific studies are, generally, more specific. An example is the following definition suggested by Dixon et al. (2014): *grassland is defined as a non-wetland type with at least 10% vegetation cover, dominated or co-dominated by graminoid and forb growth forms, and where the trees form a single-layer canopy with either less than 10% cover and 5 m height (temperate) or less than 40% cover and 8 m height (tropical).* These differences can have effect on grassland-related emission/removal estimations.

Settlements is an IPCC land-use category that can lead to confusion. It does include non-built areas, and non-sealed areas, such as urban green spaces (private gardens, public parks, etc.). The application of this category largely relies on the spatial resolution of the land use and land-use change monitoring techniques used. Using different definitions of "settlements", or "urban lands", or "artificialized areas", can lead to over- or under-estimation of carbon stock changes and therefore of CO_2 fluxes (Raciti et al., 2012).

Carbon pools are components of the climate system, other than the atmosphere. These reservoirs have the capacity to store, accumulate or release carbon (Allwood, 2014). According to IPCC GLs (2006b), they are: aboveground biomass, belowground biomass, litter, dead wood and soil organic carbon. However, according to the same reference, specific national circumstances may require modifications of them. It is also possible that some countries do not report comprehensively, providing demonstration that the none reported pools are not a source of emissions.

Although it seems that their definition does not allow great misunderstanding, in the soil case, for instance, the depth at which the carbon stock is estimated can vary among studies. Usually the literature on land use change effect focus on the upper part of the soil, as the layer that is mostly affected by disturbances, while other research studies (see for example Jobbágy & Jackson, 2000) pointed out that land use and land use chance can affect the soil organic carbon in the deeper soil profile (0 cm – bedrock). For example, LUCAS dataset considers the interval 0-20 cm (Orgiazzi et al., 2018), while FAO database includes data for 0-10, 0-30 and 0-100 cm depth intervals (Nachtergaele et al., 2009). IPCC GLs (2006b) require the estimation of soil organic carbon stock at least in the default 30 cm depth layer at tier 1 and tier 2 levels, encouraging to estimate deeper soil layers at higher complexity levels. The comparison of soil carbon stocks can be also impeded by the fact that several research projects estimates soil organic carbon stocks in different soil depth intervals (i.e. different soil volumes). Similar problems arise when stocks are estimated by the two main approaches: equivalent soil depth (Boone et al., 1999) and equivalent soil mass (Ellert and Bettany, 1995). According to the equivalent soil depth methodology, soil organic carbon stocks can be compared among equivalent soil volumes (and therefore depth intervals), while the equivalent soil mass

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procedure evades the fixed depth intervals constraint in order to compare the soil organic carbon stock in equivalent portion of soil mass.

Forest degradation generally considered as a decrease of C stocks in forests across time without corresponding to land-use change (Thompson et al., 2013). Forest degradation may also occur if there is a net decline in long-term average carbon stocks due to an increase in wood removals in managed (secondary or planted) forest. Even though it may appear that countries report degradation within “forests remaining forests”, many developing countries do not have sufficient data to provide robust estimates of the actual net C stock balance of forest land, and consequently on whether processes leading to long-term decline in carbon stocks are occurring in forest land (Federici et al., 2017).

4.3. Effect of the use of different terminology in the national reporting (UNFCCC) and climate science on GHG balance estimations

Grassi et al. (2017) and Federici et al. (2017) showed that human-induced contribution of land-use emissions (and removals) to the atmosphere reported by the IPCC AR5 and by the country reports are significantly different (Figure 2). For the period 2000-2009 the estimations are about 4.03±2.93 $GtCO_2eq/yr$ and 0.9±1.11 $GtCO_2eq/yr$, respectively. Among all the causes, the results discrepancies are mainly due to differences on the “anthropogenic effects” interpretation. The authors pointed out that other possible causes of results’ differences are: difference in land use and forest interpretations; methods adopted for the net emissions estimations; set of data adopted for each applied approach; type of processes included in the analyses; differences in temporal window investigated; incomplete reporting by countries due to capacity gaps.

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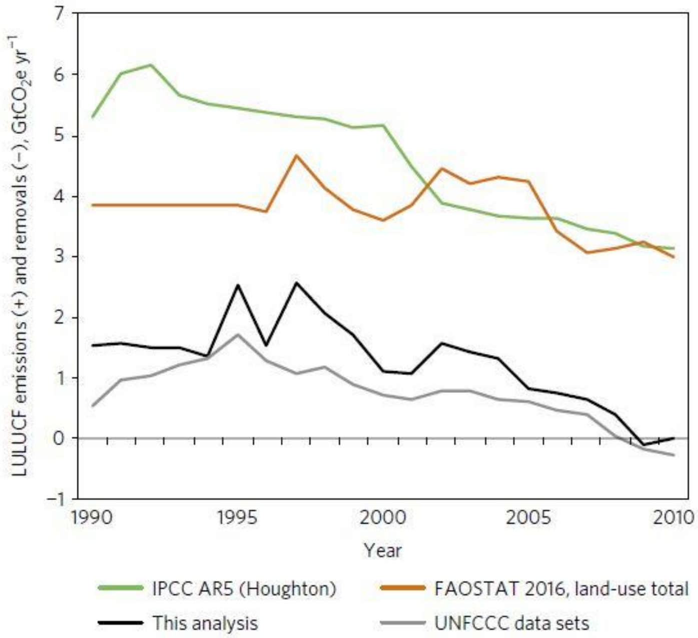

Figure 2. Comparison of historical LULCF net GHG estimated on four dataset: 1) Net GHG flux from 2016 country report under UNFCCC (in grey), 2) net GHG flux from FAOSTAT (orange line), 3) net land-use sector CO_2 anthropogenic flux include in IPCC AR5 based on bookkeeping model (Houghton et al. 2012) (green line), and 4) Grassi et al. (2017) estimation on the base of the 2016 UNFCCC Reports. Image source: Grassi et al. (2017).

According to Gasser and Ciais (2013) and Pongratz et al. (2014), terminology is a key factor to understand differences in the estimations of net GHG emissions due to LULUCF under a global point of view. Both studies distinguished direct anthropogenic LULCC activity and indirect anthropogenic LULCC activities (commonly defined as "land use feedback") and fluxes that arise due to the combination of direct LULCC effects and indirect effects mediated by environmental changes.

a. In particular, Gasser and Ciais (2013) focused on the *emission from land-use change* definition, intrinsically based on the definition of management land. The authors pointed out that there are 3 possible definitions for a global vision of the problem. *Emission from land-use change* can be defined as the sum of:

 1. i) Emissions derived from land-use change that would have been observed if land-use change activities occurred under preindustrial climate, ii) the extra emissions from land-use change due to the elevated CO_2 and N perturbations that have been affected by transitioning ecosystems, and iii) the altered land sink due to land-cover change (i.e. due to the changes in areas of the different ecosystems when compared to the preindustrial ones).

2. i), ii), iii) and iv) the global land sink that would have been observed under preindustrial land-cover.

3. i) and ii)

   The authors estimated the differences between definitions 3 and 2, and 1 and 3 up to about 20% during the period 1980s and 1990s.

b. Similarly, Pongratz et al. 2014, suggested to solve the problem of global land use and land cover change (LULCC) definition and resulting GHG net emission estimations by disaggregating direct anthropogenic and non-anthropogenic effects in all the possible land-atmosphere fluxes. The authors analysis pointed out that there are at least nine different published version of net LULCC fluxes definitions and related models that differ by a factor of 2 for the historical period considered. The net LUCC fluxes definition differ in particular for the treatment of land use feedback, the loss of additional sink capacity and the re-growth and on-site legacy effect.

4.4. Other issues

Within the GHGIs there can be differences between the *declared* definition and the *actual* definition of a specific component or category. The generic declared definition can indeed be different from the actual technical capabilities of the monitoring and observation systems. This can result in situations where the definition is not actually completely applied because the monitoring system has no sufficient (temporal or thematical or spatial) resolution to efficiently apply the criteria of the definition. For example, even if a country declares applying a forest definition that specify including the areas between 0.5 and 1 ha, it may actually not be able to monitor and report fluxes occurring on these small forest patches.

4.5. Way forward

According to Gasser and Ciais (2013), Pongratz et al. (2014) and Federici et al. (2017), at present, the most promising solution to solve *anthropogenic effects, managed land and land use* terminological differences among studies is the careful choice and declaration of the component fluxes included in the researches, or to be included in the future works. By defining better, the considered system boundaries, these expedients both increase the understanding of the components included in the estimations and facilitate the aggregation/disaggregation for study.

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5. Other sectors: summary of methods and terms in use in the GHG inventories

For the Energy, Industrial Processes and Product Use (IPPU), Agriculture and Waste sectors, there are no specific issues related to the terminology between GHGI reporting and climate science. However, it could be important to list the IPCC definitions for some terms which can lead to generic misunderstanding. In the following paragraphs the main focuses of these sectors and the most important definitions for each of them are described.

5.1. Energy – Sector 1

5.1.1. Brief introduction on reporting GL

According to 2006 IPCC GLs (2006a), energy systems are for most economies largely driven by the combustion of fossil fuels. The combustion generates heat from the chemical energy of the fuel emitting carbon dioxide (CO_2) and water (H_2O). The heat is used directly or used to produce mechanical energy for electricity and transportation.

The energy sector mainly comprises:

- Exploration and exploitation of primary energy sources;
- Conversion of primary energy sources into more useable energy forms in refineries and power plants;
- Transmission and distribution of fuels;
- Use of fuels in stationary and mobile applications.

5.1.2. Terms in use in the GHGI

Fuel combustion (activity 1A) is considered as the intentional oxidation of materials within an apparatus that is designed to raise heat and provide it either as heat or as mechanical work to a process or for use away from the apparatus (IPCC, 2006b). According to the Guidelines, only combustion processes with energy recovery are considered as combustion. Therefore, flaring is not a combustion process and it has to be reported in the fugitive sector. Even some combustion processes with energy recovery where derived gases were used (blast furnace gas, residual gases from chemical industry) are defined as industrial processes and have to be reported in CRF2.

Energy Industries (activity 1A1): in energy industries, fossil fuels are both raw materials for the conversion processes, and sources of energy to run these processes. The energy industry comprises three kinds of activities:

1. Primary fuel production (e.g. coal mining and oil and gas extraction);

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2. Conversion to secondary or tertiary fossil fuels (e.g. crude oil to petroleum products in refineries, coal to coke and coke oven gas in coke ovens);
3. Conversion to non-fossil energy vectors (e.g. from fossil fuel into electricity and/or heat).

Emissions from combustion during production and conversion processes are counted under energy industries. Emissions from the secondary fuels produced by the energy industries are counted in the sector where they are used. When collecting activity data, it is essential to distinguish between the fuel that is combusted and the fuel that is converted into a secondary or tertiary fuel in Energy Industries (IPCC 2006c).

An **autoproducer** of electricity and/or heat is an enterprise that, in support of its primary activity, generates electricity and/or heat for its own use or for sale, but not as its main business. This should be contrasted with main activity producers who generate and sell electricity and/or heat as their primary activity. Main activity producers were previously referred to as "Public" electricity and heat suppliers, although, as with autoproducers, they might be publicly or privately owned. Note that the ownership does not determine the allocation of emissions (IPCC Guidelines, 2006d). This is the theory. In reality a clear distinction between autoproducer and public energy producer is not possible.

Solid fuels include all fossil fuels with a solid consistence like coal and coal products but also derived gases which originate from coal like coke oven gas, blast furnace and basic oxygen furnace gas. Some liquid coal products like tar and benzene are also included.

Liquid fuels include all fossil fuels of a liquid quality like heating oil, diesel, gasoline etc. Since refinery gas is by-product from crude oil it's also considered as a liquid fuel.

Gaseous fuels include all fossil gaseous fuels which are original gases like natural gas and pit gas.

Biomass includes all solid, liquid and gaseous fuels which can be renewed fast. There is no specific definition of the time period. It means that these resources cannot be exhausted in human dimensions. Therefore, peat is fossil but wood is considered as biomass.

Activity data of the stationary combustion sector are fuel consumption data mostly in Joule.

Oxidation factor: normally not 100% of the carbon from fuel are released into the atmosphere. A very small amount of carbon remains as ash, dust etc. The oxidation factor is used to calculate the amount of carbon which is not emitted as CO_2 during the combustion process.

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Point source: it is a single source of emissions which can be identified precisely. A point source has a negligible extent and can be distinguished easily from other pollutant sources. Examples for point sources are large combustion plants and air ports.

5.1.3. IPCC GL relevant references

IPCC 2006a Guidelines for National Greenhouse Gas Inventories, Vol 2, Chapter 1, page 1.5
IPCC 2006b Guidelines for National Greenhouse Gas Inventories, Vol 2, Chapter 2, page 2.7
IPCC 2006c Guidelines for National Greenhouse Gas Inventories, Vol 2, Chapter2, page 2.30
IPCC 2006d Guidelines for National Greenhouse Gas Inventories, Vol 2, Chapter 2, page 2.11

5.2. Industrial Processes and Product Use (IPPU) – Sector 2

5.2.1. Brief introduction on reporting GL

According to 2006 IPCC Guidelines (2006a), GHG emissions considered under the Industrial Processes and Product Use (IPPU) Sector are those occurring from:

1. Industrial processes: the main emission sources are releases from industrial processes that chemically or physically transform materials. These activities mainly emit carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs); nitrogen trifluoride (NF_3) and sulphur hexafluoride (SF_6), the last two being used in a number of product applications as well as for special processes.
2. The use of GHG in products such as refrigerators, foams and aerosol cans. In these cases, GHGs emissions are generally delayed with respect to the manufacture of the product. This delay can vary from a few weeks to several decades. In addition, a fraction of the GHG used in the products can be recovered, recycled or destroyed at the end of the product's life.
3. Non-energy uses of fossil fuel carbon. It generally consists in the use of fossil fuel as reductants or other product in which their physical properties are used directly rather than their combustion for energy purposes.

5.2.2. Terms in use in the GHGI

The allocation of emissions of fossil fuel between the Energy and the IPPU sector in inventories can be very complex. Generally speaking, the combustion of fuels for distinct and productive energy uses has to be separated from the heat released from the use of hydrocarbons in chemical reactions defining an industrial process. Fossil fuel combustion will be reported in the Energy sector, however, when it comes to feedstock and reductants used, this allocation becomes ambiguous, also often when by-product fuels or waste gases are transferred from the manufacturing site and combusted in different parts of the process. Combustion emissions from

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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 (normally 2B and 2C). 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 1A1 or 1A2).

The main non-energy uses can be distinguished as follows:

Feedstocks are fossil fuels that are used as raw materials in chemical conversion processes in order to produce primarily organic chemicals and, to a lesser extent, inorganic chemicals and their derivates. In most cases, part of the carbon remains embodied in the product manufactured. The use of hydrocarbon feedstocks in chemical conversion processes is almost entirely confined to the chemical and petrochemical industries.

Reductants, where carbon is used as reducing agent for the production of various metals and inorganic products. It is either used directly as a reducing agent or indirectly via the intermediate production of electrodes used for electrolysis. In most cases, only very small amounts of carbon are embodied in the product manufactured, while the major part is oxidised during the reduction process.

Non-energy products that are used directly for their physical or diluent properties or which are sold to the chemical industry as a chemical intermediate. They can be fuels or be produced in refineries and also coke ovens. Lubricants and greases are used in engines for their lubricating properties; paraffin waxes are used as candles, for paper coating etc.; bitumen on roofs and roads for its waterproofing and wear qualities. White spirits are produced in refineries, and are used for their solvent properties.

5.2.3. IPCC GL relevant references

IPCC Guidelines for National Greenhouse Gas Inventories 2006a, Vol 3, Chapter 1.1, pages 1.5-1.6.
IPCC Guidelines for National Greenhouse Gas Inventories 2006b, Vol 3, Chapter 1.2-1.3, pages 1.7-1.15.

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5.3. Agriculture – Sector 3

5.3.1. Brief introduction on reporting GL

Agriculture contributes to global anthropogenic greenhouse gas emissions as a result of the following activities:

- CH_4 emissions from enteric fermentation;
- CH_4 and N_2O emissions from direct and indirect manure management;
- CH_4 emission from rice cultivation;
- N_2O direct and indirect emission from managed soils;
- CH_4 and N_2O Emission from field burning of agriculture residues;
- CO_2 emission from liming and urea application.

Reporting issues raised by the inventory agencies involved in VERIFY are related to:

1. The fact that in the IPCC guidelines it's not completely clear how to deal with import and export of manure. Is it allowed to subtract the amount of manure that is exported from the total amount of manure? And besides: there seems to be some discrepancy between the reported amount of manure exported, and the amount of manure imported by other countries.
2. The amount of animals in the agricultural sector. For instance: "hobby – horses" (or cows). Should they be added to the total amount of horses in the sector or not?

5.3.2. Terms in use in the GHGI

Enteric fermentation (CRF table 3A1) is the process of a digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for absorption into the bloodstream (IPCC, 2006). A by-product of this process is methane (CH_4), which is emitted into the atmosphere. These emissions are calculated for 3A1ai Dairy Cows, 3A1aii Non-dairy Cattle, 3A1b Buffalo, 3A1c Sheep, 3A1d Goats, 3A1e Camels, 3A1f Horses, 3A1g Mules and Asses, 3A1h Swine and 3A1j Other.

Manure management (CRF table 3A2) includes the storage of livestock manure. During anaerobic condition the decomposition of manure will cause methane and nitrous oxide to be emitted (IPCC, 2006). How much CH_4 and N_2O are produced depends; manure characteristics (amount of nitrogen and volatile solids present in the manure) and manure management systems characteristics (temperature, retention time). So for each combination of livestock category and manure management system a different emission factor should be calculated. The animal categories are; for 3A1ai Dairy cattle, 3A1aii Non-dairy cattle, 3A1b Buffalo, 3A1c Sheep,

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3A1d Goats, 3A1e Camels, 3A1f Horses, 3A1g Mules and Asses, 3A1h Swine, 3A1j Poultry and 3A1i Other animals.

Liming (CRF table 3C2) includes the CO_2 emissions of calcic limestone ($CaCO_3$), or dolomite ($CaMg(CO_3)_2$) used in agriculture.

Direct and indirect N_2O emission from agricultural soils (CRF tables 3C4, 3C5 and 3C6) includes the direct N_2O emissions from managed soils from the synthetic N fertilizers application; organic N applied as fertilizer (e.g. animal manure, compost, sewage sludge, rendering waste); urine and dung N deposited on pasture, range and paddock by grazing animals; N in crop residues (above and below ground), including from N-fixing crops and from forages during pasture renewal; N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils; and drainage/management of organic soils (i.e., histosols) (IPCC, 2006). Indirect N_2O emissions from: (1) the volatilization of N (as NH_3 and NOx) following the application of synthetic and organic N fertilizers and/or urine and dung deposition from grazing animals, and the subsequent deposition of the N as ammonium (NH_4^+) and oxides of N (NOx) on soils and waters, and (2) the leaching and runoff of N from synthetic and organic N fertilizer additions, crop residues, mineralization/immobilization of N associated with loss/gain of soil C in mineral soils through land use change or management practices, and urine and dung deposition from grazing animals, into groundwater, riparian areas and wetlands, rivers and eventually the coastal ocean (IPCC, 2006). Figure 3 gives a visual representation of these emissions.

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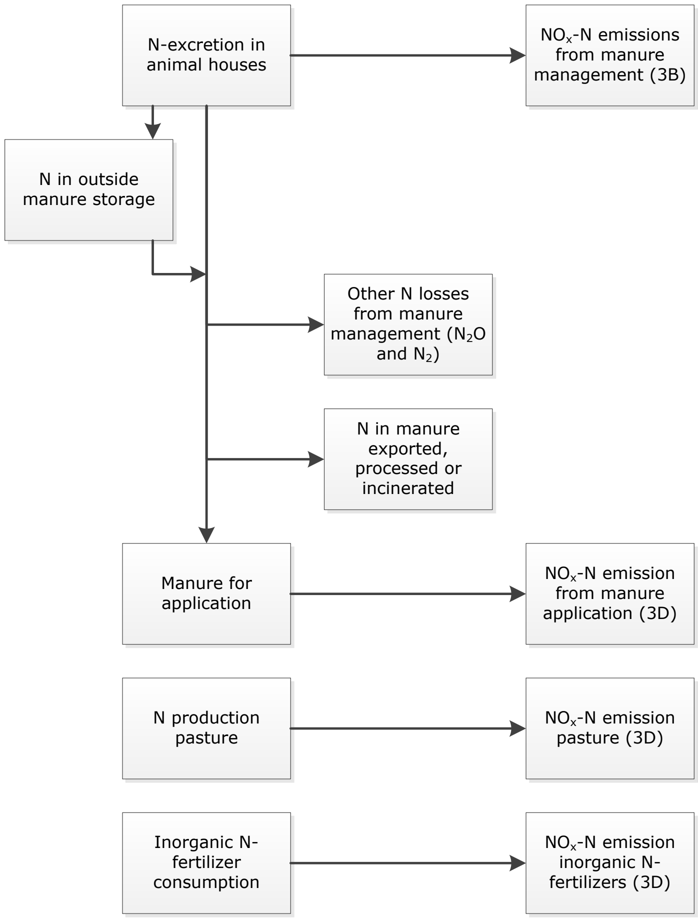

Figure 3. Nitrogen flows in relation to NOx emissions

5.3.3. IPCC GL relevant references

IPCC Guidelines for National Greenhouse Gas Inventories 2006, Vol 4, Chapter 10 and 11.

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5.4. Waste – Sector 4

5.4.1. Brief introduction on reporting GL

Waste sector, as reported in the national GHGIs, includes the following sub-sector emissions (IPCC, 2006):

- Solid waste disposal (CRF 5A);
- Biological treatment of solid waste (CRF 5B);
- Incineration and open burning of waste (CRF 5C);
- Wastewater treatment and discharge (5D).

Reporting issues raised by the inventory agencies involved in VERIFY are related to:

- The split between biogenic and non-biogenic emissions;
- The temporal variability of emissions (accidental fires…);
- The reporting of emissions from illicit activities.

The main misunderstanding relating to the waste sector terminology deals with allocation rules as waste related emissions are supposed to be allocated to other CRF sectors (energy, agriculture…).

5.4.2. Terms in use in the GHGI

Solid waste disposal (5A) corresponds to the disposal of municipal, industrial and other solid waste in locations where they are stored, named "Solid Waste Disposal Sites (SWDS)" in the IPCC Guidelines (2006). This category includes emissions from advanced landfills with management practices, but also does include emissions from unmanaged landfills (dumps). In landfills, the GHG emissions are mainly diffuse emissions resulting from the degradation of organic waste, however other activities occur on SWDS that may be sources of GHG, such as fires (accidental or as a management practice), waste transport and handling, wastewater storage and treatment, biogas epuration and combustion (flaring or energy production), biomethane injection, etc. In terms of reporting, emissions from managed and unmanaged are supposed to be reported separately in the CRF 5A, respectively under 5A1 and 5A2. Emissions from other activities are supposed to be reported in other CRF categories: 5C for waste burning, 5D for wastewater treatment, 1A1a for waste to energy activities etc.

Biological treatment of solid waste (5B) corresponds to composting and anaerobic digestion of organic waste.

Incineration and open burning of waste (5C) corresponds to the industrial combustion and to the combustion of unwanted combustible materials.

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The category "Incineration" (5C1) covers industrial combustion of all types of waste (municipal, industrial, hazardous, clinical, and sewage sludge) and may occur with or without energy recovery. Emissions from incineration with energy recovery must be reported in the energy sector while emissions from incineration without energy recovery have to be reported under the waste sector (5C). Anyway, both must be reported with a distinction between fossil and biogenic origin.

The category "Open burning" (5C2) covers burning as a management practice (illicit or not), such as in some landfills to decrease the volume waste or domestic burning of garden waste and includes accidental fires (municipal waste landfills, tyres, etc.). Both must be reported with a distinction between fossil and biogenic origin. This category does not include on-field agricultural waste burning.

Wastewater treatment and discharge (5D) covers centralised and non-centralised treatment of domestic and industrial wastewater and also includes wastewater discharge of treated and untreated wasters in the environment. In addition, emissions from sludge treatment occurring on the wastewater treatment plants (WWTP) have also to be report in this CRF category. Emissions from sludge treatment occurring outside from the WWTP must be reported in other sectors (e.g. sludge spreading in agriculture, incineration in 5C…).

5.4.3. IPCC GL relevant references

IPCC Guidelines for National Greenhouse Gas Inventories 2006, Vol 5, Chapters 2 to 6.

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6. Final considerations

This first investigation process pointed out that terminological issues between IPCC GLs and climate science affects mainly the LULUCF sector. These issues can significantly affect the GHG reporting and climate science estimations. Grassi et al. (2017) and Federici et al. (2017) estimated that, for the period 2000-2009, results discrepancies between country reports under UNFCCC and AR5 are about 4.03±2.93 $GtCO_2eq/yr$ and 0.9±1.11 $GtCO_2eq/yr$, respectively. Similar discrepancies pointed out the urgent needs for interoperability requirement in order to clearly achieve the 2°C temperature goal established under the Paris Agreement.

However, it does not exist any specific solution for terminological issues, at present, according to Gasser and Ciais (2013), Pongratz et al. (2014) and Federici et al. (2017), the most promising solution to solve it consist in a careful choice and declaration of the component fluxes included in the climate science, in order to give the possibility to policymakers to include in the NIRs and BURs compilation what is requested by the steady IPCC GLs structures.

Another possible solution is that proposed by Leip et al. (2018). According to the authors it is necessary to invest significantly in the field of atmospheric measurements and models with the creation of a dense monitoring network (for example of eddy covariance towers and bedrooms). The subsequent application of inversion models for the cross-check of the estimated data would then allow to apply top-down approaches to the reporting world, possibly solving problems of scarce accuracy related to the use of low complexity tiers (level 1 and 2) in the NIRs composition.

Similarly to the first LULUCF terminological issues solution, policymakers from all the sectors significantly encourage the research world to be rigorous in the use of IPCC GLs terminology and system boundaries definitions. Indeed, by defining better the considered system boundaries, these expedients both increase the understanding of the components included in the estimations and facilitate the aggregation/disaggregation for study.

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