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Towards common GHG inventory reporting tables for Biennial Transparency Reports

Experiences with tools for generating and using reporting tables under the UNFCCC

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Foreword

This document was prepared by the OECD and IEA Secretariats in response to a request from the Climate Change Expert Group (CCXG) on the United Nations Framework Convention on Climate Change (UNFCCC). The Climate Change Expert Group oversees development of analytical papers for the purpose of providing useful and timely input to the climate change negotiations. These papers may also be useful to national policy-makers and other decision-makers. Authors work with the CCXG to develop these papers. However, the papers do not necessarily represent the views of the OECD or the IEA, nor are they intended to prejudge the views of countries participating in the CCXG. Rather, they are Secretariat information papers intended to inform Member countries, as well as the UNFCCC audience.

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Abstract

Towards common GHG inventory reporting tables for Biennial Transparency Reports: Experiences with tools for generating and using reporting tables under the UNFCCC

Under the Enhanced Transparency Framework (ETF) of the Paris Agreement, Parties will be required to report information on national GHG inventories using a set of Common Reporting Tables (CRTs). The CRTs can provide an important source of data at the international and national levels. While a final set of tables has not yet been agreed upon, there is an emerging convergence around the view that the Common Reporting Format (CRF) tables that Annex I Parties currently use to report national GHG inventories could serve as a starting point for the development of CRTs. To support ongoing discussions, this paper provides details on the structure and functions of the existing CRF tables and the CRF Reporter software used to generate the tables, as well as some countries' experiences with using this current system. To facilitate the transition towards reporting using CRTs, the paper also provides an overview of other tools that could support countries in reporting GHG inventories through CRTs and outlines a set of key issues that could be considered in the transparency negotiations. The paper concludes that the use of CRF tables and a CRF Reporter reduces the reporting burden on Parties – and that this could also be a significant benefit of CRTs and a CRT reporter. The paper also highlights that countries' experience shows that effective IT arrangements can facilitate the reporting process but that as developing countries have no prior experience with the use of CRF tables and the CRF Reporter, the transition to a new CRT system may need capacity-building support, including for setting up suitable IT arrangements.

JEL Classification: F53, Q54, Q56, Q58

Keywords: UNFCCC, Paris Agreement, Enhanced Transparency Framework, reporting, GHG inventories.

Résumé

Des tableaux communs d'inventaire de GES pour les rapports biennaux de transparence : Retour sur les outils utilisés pour créer et exploiter des tableaux de notification au titre de la CCNUCC

Le cadre de transparence renforcé défini dans l'Accord de Paris impose aux Parties de communiquer des informations sur les inventaires nationaux de GES à l'aide de tableaux communs, lesquels pourraient donc constituer une importante source de données aux niveaux national et international. S'il reste à convenir de la forme définitive que prendront ces tableaux, les avis commencent à converger vers la possibilité de s'inspirer du cadre commun de présentation dont les Parties visées à l'Annexe I se servent actuellement pour rendre compte de leurs inventaires nationaux de GES. À l'appui de la réflexion en cours, le présent document offre une description détaillée de la structure et des fonctions de ce cadre et du logiciel connexe qui sert à créer les tableaux, ainsi que des informations sur la manière dont le système actuel est exploité dans certains pays. Pour faciliter le passage à la notification fondée sur le cadre commun de présentation, d'autres outils susceptibles d'aider les pays à communiquer leurs inventaires de GES par ce moyen sont également passés en revue, de même que l'attention est attirée sur les grandes questions à aborder dans les négociations sur la transparence. La conclusion qui s'en dégage est que le recours au cadre commun de présentation et au logiciel connexe allège la charge déclarative des Parties, ce qui constitue certainement un avantage non négligeable. Les auteurs constatent également que des processus informatiques efficaces facilitent l'exercice mais que les pays en développement n'ayant pas encore eu affaire au cadre commun de présentation et au logiciel connexe, il faudra probablement les aider à se doter des capacités requises, notamment sur le plan informatique, pour réussir la transition vers le nouveau système de tableaux communs.

Classification JEL : F53, Q54, Q56, Q58

Mots-clés : CCNUCC, Accord de Paris, Cadre de transparence renforcé, notification, inventaires de GES.

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Acronyms

BR	Biennial Report
BUR	Biennial Update Report
CCXG	Climate Change Expert Group
CMA	Conference of the Parties serving as the meeting of the Parties to the Paris Agreement
COP	Conference of the Parties
CRF	Common Reporting Format
CRT	Common Reporting Table
ETF	Enhanced Transparency Framework
GHG	Greenhouse gas
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IT	Information Technology
KCA	Key Category Analysis
MPGs	Modalities, Procedures and Guidelines
MRV	Measurement, Reporting and Verification
MS	Microsoft
NC	National Communication
OECD	Organisation for Economic Co-operation and Development
QA/QC	Quality Assurance / Quality Control
SBSTA	Subsidiary Body for Scientific and Technological Advice
UNFCCC	United Nations Framework Convention on Climate Change

Glossary

Activity data	Activity data indicates the annual magnitude of an activity taking place over a given timeframe (e.g., annual amount of waste treated). Activity data is one of the two components, along with emission factors, needed to estimate GHG emissions of a category.
Annex I Parties	Parties listed in Annex I of the UNFCCC. According to Decision 3/CP.1, these Parties are to submit a national GHG inventory on an annual basis under the current MRV framework (UNFCCC, 1995 ^[1]).
Common Reporting Format (CRF) tables	The Common Reporting Format (CRF) tables are a set of tables that Annex I Parties are required to use under current reporting arrangements to report their national GHG inventories to the UNFCCC. The CRF Reporter generates the CRF tables.
CRF Reporter	The CRF Reporter is a web-based software developed by the UNFCCC Secretariat to facilitate Annex I Parties' GHG inventory reporting to the UNFCCC. The CRF Reporter generates the CRF tables.
Common Reporting Tables (CRTs)	The Common Reporting Tables (CRTs) are a set of tables that all Parties to the Paris Agreement will be required to use, starting in 2024, to report their national GHG inventories to the UNFCCC. The CRTs' structure is currently under discussion; the tables are expected to be finalised by COP26 in 2021. A software developed by the UNFCCC will likely generate the CRTs, hereinafter referred to as the CRT Reporter (no official name has been agreed yet).
Developed / Developing countries	The Paris Agreement does not refer to Annex I and non-Annex I countries but developed and developing countries. In this paper, the terms Annex I / non-Annex I countries are used where current GHG inventory reporting requirements are mentioned, developed/developing countries where the ETF reporting requirements are mentioned.
Emission factor	Emission factors are coefficients that allow for activity data to be converted into GHG emissions and are expressed as the average mass of GHG emitted by a given source relative to units of activity or processes (e.g., CH ₄ per tonne of waste treated).
IPCC Inventory Software	The IPCC Inventory Software is an MS-Access-based software programmed to assist Non-Annex I Parties in estimating national GHG emissions. The Software can facilitate Non-Annex I Parties' reporting as it allows exporting reporting tables for GHG inventories that are consistent with reporting guidelines of Non-Annex I Parties' National Communications.
Key Category and Key Category Analysis (KCA)	As defined by the IPCC, "a key category is prioritised within the national inventory system because its estimate has a significant influence on a country's total inventory of greenhouse gases in terms of the absolute level, the trend, or the uncertainty in emissions and removals. Whenever the term key category is used, it includes both source and sink categories." (IPCC, 2006 ^[2]) The identification of a country's key categories occurs through the Key Category Analysis, which is described in Volume 1, Chapter 4 of the 2006 IPCC Guidelines.
MS Access	Microsoft Access is a database management system (DBMS).
MySQL	MySQL is a freely available and open-source Relational Database Management System (RDBMS). It can be used for adding, accessing, and managing content in a database.
Non-Annex I Parties	Parties not listed under Annex I of the UNFCCC. Under the current MRV framework, these Parties submit national GHG inventories as part of National Communications and Biennial Update Reports.
Notation Keys	The IPCC 2006 Guidelines stipulate that it is good practice to fill in information for all GHG inventory reporting tables' entries. Where actual emission and removal quantities have not been estimated or cannot otherwise be reported in the tables, the inventory compiler should use notation keys (e.g., NE – not estimated and IE – included elsewhere) and provide supporting documentation.
Quality assurance (QA)	As defined by the IPCC, Quality Assurance (QA) "is a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process. Reviews, preferably by independent third parties, are performed upon a completed inventory following the implementation of QC procedures" (IPCC, 2006 ^[2]).
Quality control (QC)	As defined by the IPCC, Quality Control (QC) "is a system of routine technical activities to assess and maintain the quality of the inventory as it is being compiled. It is performed by personnel compiling the inventory" (IPCC, 2006 ^[2]).
R	R is a free software for statistical computing.
Tier	The IPCC has classified the methodological approaches for calculating GHG emissions into three different Tiers: Tier 1, Tier 2, and Tier 3. Higher tiers allow for the production of more accurate GHG emission estimates but are more methodologically complex and need more detailed background data. Tier 1 applies default emission factors, Tier 2 applies national emission factors, and Tier 3 applies national models and direct measurements.
XML	Extensible Markup Language. Generates formats that are both human-readable and machine-readable
.xlsx	Microsoft Excel file format, a spreadsheet file format. XLSX is a proprietary format, and therefore Microsoft holds its intellectual rights.

Executive Summary

The Enhanced Transparency Framework (ETF) of the Paris Agreement introduces a new reporting framework for all Parties to improve the availability and transparency of information reported and enhance the understanding of the global response to climate change. According to the ETF, Parties will be required to report information i.a. on national greenhouse gas (GHG) inventories. This information on GHG inventories is to be reported using a set of Common Reporting Tables (CRTs). The Subsidiary Body for Scientific and Technological Advice (SBSTA) is requested to develop these CRTs, which are thereafter to be adopted by the third Conference of the Parties serving as the meeting of the Parties to the Paris Agreement (CMA3), scheduled to take place in November 2021. Parties have been negotiating CRTs since 2018 and, while some progress has been made, a set of tables has not yet been agreed as several sticking points, mostly political, remain unresolved. For example, Parties have not yet agreed on the structure of tables that are to be included in the set of CRTs nor on how to include reporting elements that have been introduced by the ETF within the tables.

Reporting national GHG inventories is already mandatory for all Parties under the United Nations Framework Convention on Climate Change (UNFCCC). However, Annex I and non-Annex I Parties have been following different reporting guidelines, reporting at different frequencies, and using different reporting formats. Parties' current experience in preparing and reporting national GHG inventories is a central issue to be taken into account when negotiating CRTs. Annex I Parties' experience is considerable because these Parties have been reporting GHG inventories using a common set of tables, the Common Reporting Format (CRF) tables, on an annual basis since 2000. Furthermore, paragraph 12 of decision 18/CMA.1 requests that the development of the CRTs takes into account existing CRF tables. These CRF tables are widely accepted to be a good starting point for the development of CRTs. To generate the CRF tables, Annex I Parties are requested to use the "CRF Reporter" software developed by the UNFCCC. This software is likely to be the basis for developing a dedicated software to be developed for CRTs, hereafter referred to as the "CRT Reporter," noting that there is no agreed terminology yet on the name of the software. The more limited experience of Non-Annex I Parties in reporting using a common format due to their less prescriptive reporting guidelines to date is less extensive but equally important. This is because the CRTs will need to be designed in such a way as to accommodate the agreed flexibility provisions outlined in the Modalities, Procedures, and Guidelines (MPGs) so that they can be used by those developing country Parties that need them in the light of their capacities.

To support ongoing transparency discussions on the development of CRTs, this paper provides details on the structure and functions of the existing CRF tables and the CRF Reporter to facilitate understanding of how this current system works. It also explores some countries' experiences using this current system and the key challenges faced in its implementation. The paper also presents other tools and countries' experiences that could facilitate the transition towards a CRT system. To provide further input to the transparency discussions, the paper highlights insights on how the current CRF tables, once submitted, are used. Drawing upon these elements, the paper identifies the following key messages:

- **Using the CRF Reporter significantly reduces the reporting burden on Parties.**

There are 49 CRF tables for reporting GHG inventories under the Convention. The CRF Reporter offers a set of functions whereby a given data point reported once by the Party is automatically filled in or aggregated for corresponding cells in other relevant tables. For example, emission data provided at the category level in the background data tables are used to fill in emission values in

sectoral and summary tables automatically. This reduces the Party's reporting burden, the resources needed for reporting, and human error risk. Nevertheless, the CRF Reporter is a reporting tool, not a calculation tool. Therefore, GHG emissions need to be estimated beforehand through other software and tools and then fed into the CRF Reporter.

- **Activity data needed to complete the CRF background data tables is fundamental to GHG emissions calculation and does not necessarily represent an increase in data collection efforts.**

Data reported in the background data tables include GHG emissions and activity data needed to calculate these emissions. Implied emission factors, which are also provided in the background data tables, are automatically calculated by the CRF Reporter.

- **Information Technology (IT) solutions can significantly reduce the resources needed for reporting GHG inventories through CRF tables, and countries' experience shows that effective IT arrangements for this purpose can apply commonly-used software.**

To estimate emissions and to produce files that can be fed into the CRF Reporter to generate CRF tables, many Annex I Parties apply commonly-used software such as MS Excel, MS Access, R, and MySQL. Some software tools (e.g., MS Excel) require only basic IT skills yet offer significant opportunities to prepare GHG inventories efficiently. These software tools can be combined in an IT system that can facilitate the procedures of organising and standardising collected data, estimating GHG emissions, and formatting values and data in a format that can be automatically processed by the CRF Reporter, which will then generate the CRF tables. Some Parties have also developed bespoke software and platforms to automate data collection, further facilitating the inventory compilation process.

- **Developing countries have no prior experience with the use of CRF tables and the CRF Reporter for reporting purposes; the transition to a CRT system may need capacity-building support in setting up suitable IT arrangements.**

When considering GHG inventories' reporting, a central challenge for developing countries with limited reporting experience and technical capacity may be that of organising activity and emission data in a format that can be easily inputted into the CRT Reporter, minimising the additional reporting burden. Under current reporting arrangements, developing countries are not required to report using the CRF tables and the CRF Reporter and have not had the opportunity to develop and test IT arrangements that can facilitate CRF/CRT-reporting. Experience from other countries shows that having such a system in place can be helpful, and sustained capacity-building support through existing and new international platforms will likely be necessary for the future to assist developing countries with the transition to a new CRT reporting system.

- **The free and publicly available IPCC Inventory Software can potentially play an important role in further facilitating developing country reporting of national GHG inventories through a CRT system.**

The IPCC Inventory Software is primarily a calculation tool, as it allows countries to estimate GHG emissions based on activity data entered. The Software can also assist countries in reporting their national GHG inventories, as it outputs relevant data in tabular formats compatible with existing non-Annex I reporting requirements. Once all relevant data for GHG estimation in all sectors has been entered, the IPCC Inventory Software includes all data necessary for filling in the CRF reporter tables. The reporting tables generated by the IPCC Inventory Software are at present not compatible with the CRF Reporter; that is, they cannot directly feed into the CRF Reporter. However, the IPCC plans to potentially add this feature in the future once the CRTs' format is agreed upon and dependent on resources' availability. An adapted IPCC Inventory Software that can generate reporting tables that directly feed into a CRT Reporter would represent an advantageous solution for countries with limited reporting capacity and that use lower tiers for estimating their GHG emissions.

- **The level of reporting burden¹ depends more on the availability and characteristics of the IT and institutional arrangements in place and of the reporting software used than on the numbers of reporting tables and their formats.**

While the clear mandate of the SBSTA is that of developing a set of CRTs, it is important to note that once the relevant data points have been entered into the CRT Reporter, these could, in theory, be presented in any tabular format desired and included in multiple tables offering different levels of aggregation, e.g., at category level, but also aggregated at sectoral and/or national level. The numbers of tables to be reported and their specific formats do not, therefore, determine the level of reporting burden on Parties. Factors that will influence the reporting burden include the approach to data entry, such as the software's ability to communicate with software solutions for GHG inventory compilation like the IPCC Inventory Software.

- **When discussing CRTs, it may be important to consider the CRTs' uses beyond UNFCCC reporting and benefits at the national and international level.**

CRTs are an important source of data for the international community, e.g., for research purposes, reviews under the UNFCCC, input to the global stocktake, and at the national level, e.g., to support effective policy design, assess implementation, enhance transparency. Reporting such data in a machine-readable format greatly facilitates its use for purposes beyond UNFCCC Reporting where data is to be aggregated (e.g., total global GHG emissions) or compared (e.g., among countries, between reporting years). The current CRF tables are not fully machine-readable, while another possible output of the CRF Reporter, an XML file, is. It is worth considering whether a CRT Reporter could be designed to output CRTs that are machine-readable and whether the XML-files generated by a CRT Reporter could be made publicly available to facilitate the use of this data for wider benefits.

¹ While there are of course country-specific factors increasing reporting burden, such as availability of internet access, availability of IT hardware/software, institutional arrangements etc., this paper focuses on the reporting burden resulting from the common reporting framework itself.

1. Introduction

National GHG inventories are a key component of Parties' reporting to the United Nations Framework Convention on Climate Change (UNFCCC). Reporting information on national greenhouse gas (GHG) emissions is currently mandatory for all Parties under the Convention. However, Annex I and non-Annex I Parties report such information following different reporting guidelines, with a different frequency, and using different reporting formats and timelines. In particular, Annex I Parties report following more stringent reporting guidelines and using a common set of tables, the Common Reporting Format (CRF) tables, and a common software, the CRF Reporter (UNFCCC, 2013^[3]). Non-Annex I Parties report less often, following less stringent reporting guidelines and mostly using nationally-determined and less detailed tabular formats (UNFCCC, 2003^[4]).

The Enhanced Transparency Framework (ETF) of the Paris Agreement introduces a new reporting framework for all Parties to strengthen the availability and transparency of information reported by Parties. The ETF requires or requests Parties to report on a number of elements, including national GHG inventories, support provided, mobilised needed and received and information on progress made in implementing and achieving NDCs. Under the ETF, all Parties will be required to regularly report national GHG inventories using a common set of guidelines and a set of Common Reporting Tables (CRTs) (see Box 1). These tables will accompany a National Inventory Document (NID), which would document methodological choices, describe institutional arrangements and national circumstances and provide references and sources of information used for activity data. The NID may be reported as part of the BTR or as a standalone report. Parties are expected to implement the new reporting requirements outlined in the ETF by December 2024, when the first Biennial Transparency Report (BTR) is due. Reporting guidelines for the preparation of national GHG inventories using CRTs are laid out in the Modalities, Procedures and Guidelines (MPGs) included in the Annex to decision 18/CMA.1 and adopted at COP24 in 2018 (UNFCCC, 2019^[5]).

The design and structure of the set of CRTs to be developed have been under discussion amongst Parties since 2018. Decision 18/CMA.1 requests the Subsidiary Body for Scientific and Technological Advice (SBSTA) to develop CRTs, which are thereafter to be adopted by the third Conference of the Parties serving as the meeting of the Parties to the Paris Agreement (CMA3). Existing CRF tables could provide a good starting point for the development of CRTs; yet, CRTs would have to be adjusted so to allow for the reporting of new reporting elements and to accommodate the specific flexibilities agreed in the MPGs for developing country Parties that need them in light of their capacities. A set of tables has not been agreed upon yet, and several sticking points, mostly political, remain unresolved. For example, Parties have not yet found an agreement concerning what tables are to be included in the set of CRTs and how to include, within the tables, new reporting elements that have been introduced with the ETF. Concerns related to the need to build developing countries' capacity for reporting GHG inventories have characterised discussions on CRTs' development. Indeed, as the ETF's guidelines for GHG inventories and CRTs do represent a step up in current non-Annex I Parties' reporting requirements, the need for capacity building is well acknowledged in the formal negotiations

Ongoing negotiations on the development of CRTs can benefit from a comprehensive understanding of the current structure of CRF tables and the functioning of the CRF Reporter, their use, and the broader process of preparing a GHG inventory. CRTs come into play only in the last steps of the inventory process,

i.e., in the reporting phase. Yet, the inventory process is a complex one. The way it is set up domestically can influence the amount of time and the resources needed to estimate emissions and generate the CRTs. To familiarise developing countries with which institutional and IT arrangements could be needed domestically to compile a GHG inventory and report using CRTs, this paper highlights experience from selected countries and provides an overview of the tools that may facilitate the transition to a CRT system.

Furthermore, understanding how CRF tables are used once submitted to the UNFCCC and by whom can provide insights to the negotiations on the CRTs' structure and design. This, in turn, will offer the opportunity to design a set of tables that render information on national GHG inventory data more transparent for researchers, organisations, and the international community. Building upon insights from current experience in generating and using the CRF tables, potential challenges that countries with limited reporting capacity may face, as well as opportunities that a CRT system can offer to reduce reporting burden, the last chapter of this paper provides a set of annotated questions that may provide useful input to the ongoing transparency discussions.

Box 1. Reporting national GHG inventories through CRTs

Quantitative and qualitative information on GHG inventories can potentially be reported in many formats. CRTs are a template for the electronic reporting of GHG data under the UNFCCC specifically and are a central element of the Paris Agreement's ETF. CRTs can allow all Parties to transparently report information on national GHG inventories using a standardised and common format, in turn promoting Transparency, Accuracy, Consistency, Comparability, and Completeness (TACCC) (Falduto, Wartmann and Rocha, 2020^[6]).

- **What are CRTs?**

CRTs are a set of tables in which Parties can report (mostly) quantitative information on national GHG emissions. Such information will include reporting emission values by GHG, sector, category, activity data, and implied emission factors. CRTs can also allow Parties to report some qualitative information, e.g., providing information on scope or justifications for not estimating certain values. The CRTs will likely be generated by a dedicated software developed by the UNFCCC Secretariat (hereinafter the CRT Reporter) and will likely be available in various electronic and machine-readable formats, including MS Excel format (.xlsx) and Extended Markup Language (XML).

- **Why is it useful to report using CRTs?**

Reporting quantitative information on national GHG emissions in an electronic tabular format facilitates the readability and elaboration of the data that it contains. The additional qualitative data, such as notation key explanations, help to put the quantitative information into context. Using a common set of reporting tables facilitates the comparability of data across countries and aggregation of data. Using a machine-readable, electronic format (i.e., that can be easily processed by a computer) can facilitate the work of many UNFCCC processes, organisations, and institutions of compiling and analysing the data that these tables contain, including the technical expert review process established in section VII or the MPGs (UNFCCC, 2019^[5]).

- **Who will use the CRTs?**

The CRTs provide key information on national GHG emissions that can be accessed by the international community to, e.g., assess current levels and historical trends of global GHG emissions. Once submitted to the UNFCCC, countries' CRTs will likely be publicly available as MS Excel (.xlsx) files on the UNFCCC website. As is currently the case with Annex I Parties' CRF tables, CRTs can be used by international organisations, academia, and experts to produce analysis on the state of global GHG emissions. Furthermore, the CRTs are also subject to the Technical Expert Review (TER) under the Paris Agreement and could potentially play an important role in providing input to the Global Stocktake (see (Falduto, Wartmann and Rocha, 2020^[6])). Beyond their use for the international community, CRTs can be particularly useful at the national level. They can in fact provide key information to policy- and decision-makers and support the design and implementation of policies and mitigation strategies.

Source: Authors

2. Current approaches to GHG-inventory preparation and reporting

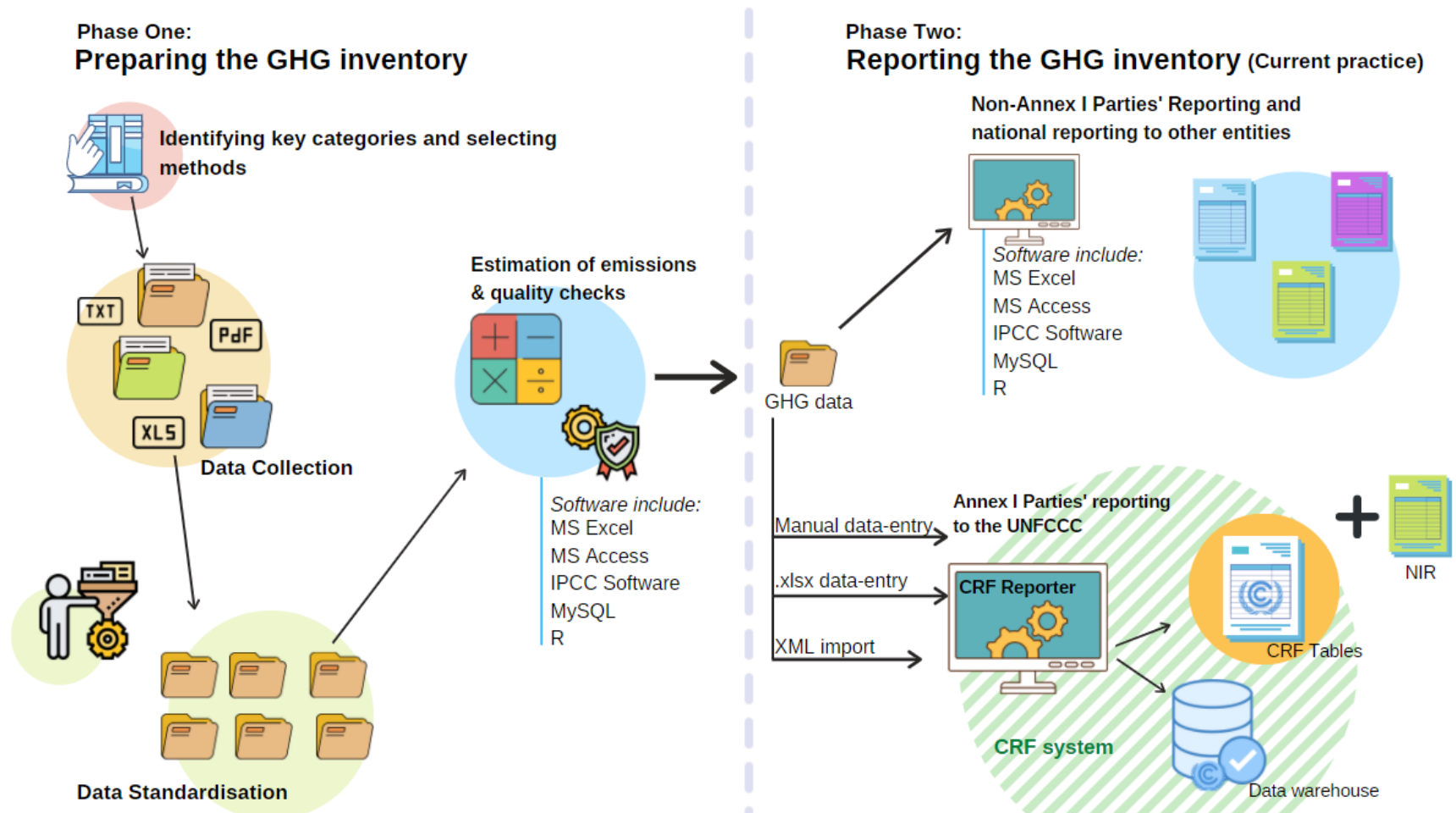
This section provides an overview of how national GHG inventories are currently prepared and reported to the UNFCCC. This chapter first presents the key steps of the GHG inventory process. It then presents the tools presently used by Annex I Parties for their national GHG inventory reporting, i.e., the CRF tables and the CRF Reporter. Finally, the chapter presents experiences and approaches in generating GHG inventory data as input for the CRF Reporter and using the outputs of the CRF Reporter, for example, for research activities and reviews under the UNFCCC. To facilitate understanding of the concepts expressed in this chapter, terms in **blue bold** are included in the Glossary at page 10.

2.1. Preparing and reporting a national GHG inventory

Preparing and reporting a national GHG inventory can be viewed as separate phases of the inventory process. To prepare a GHG inventory (phase one), relevant data is collected, and GHG estimates are produced according to established methodologies, i.e., the IPCC Guidelines for National Greenhouse Gas Inventories.² To report a GHG inventory (phase two), the estimated emissions and other complementary information such as, e.g., methodologies adopted and informative background data are organised and formatted according to agreed reporting guidelines and communicated to national or international entities. Key steps of the process are illustrated in Figure 1. While the implementation of phase one (inventory preparation) is crucial to facilitate phase two (reporting), the mandate of the SBSTA is focused on phase two, and particularly on the development of CRTs to help Parties report results and background data used in and produced by phase one. This section provides an overview of the whole inventory process to provide relevant context.

² Throughout the years, the IPCC has developed and released methodologies for the preparation of national GHG inventories; such methodologies have been regularly updated so to reflect the latest science. Existing methodology guidelines include (in chronological order): Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1996^[19]), 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006^[2]), 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019^[20]). Supporting methodology to the main IPCC Guidelines include: Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000^[16]), Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC, 2003^[17]), 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (IPCC, 2013^[18]). To prepare national GHG inventories under the UNFCCC, only Annex I Parties are currently required to use the 2006 IPCC Guidelines. Under the ETF, all Parties will be required to use the 2006 IPCC Guidelines. The 2019 Refinement has not been yet been adopted by the CMA and may be used by Parties on a voluntary basis.

Figure 1. Key steps of the current GHG inventory process



Source: Authors

Unclassified

2.1.1. Phase One: Preparing the GHG inventory

Preparing the GHG inventory is the lengthiest phase of the inventory process. Insights from Parties' current experience indicate that even for countries with long-standing experience in reporting GHG inventories annually, it can still take up to 10 months to prepare a GHG inventory. With less experience, the step can take considerably longer. Regularly preparing a national inventory can facilitate this compilation process over time. The complexity and structure of institutional and IT setups for this phase can vary considerably across countries, depending on the specific national circumstances. During this phase, several different institutions and entities may be involved. Key steps³ of this first phase include:

- **Identifying key categories and selecting GHG estimation methods**

The first step for a revised or new GHG inventory is to identify the key categories for the inventory so that resources available for the inventory preparation can be prioritised. Once the key categories have been identified, the inventory compiler can select the appropriate methods estimating emissions, depending on the country's specific national circumstances. The selection of methods will be determined by whether a category has been classified as key or not key, and by both the data and the resources available.

- **Collecting relevant data**

Information needed to produce GHG estimates needs to be collected. This includes activity data for GHG emission categories or carbon sinks and other informative background data required to compile emission factors and/or other calculation factors, as applicable. Data sources usually include ministries, academia, industries, and other organisations. Countries with robust GHG-inventory systems typically put in place formal institutional arrangements and legal instruments to ensure that relevant data providers regularly communicate activity data. Data collection can prove to be one of the most challenging inventory-preparation steps, as relevant data is not always available to inventory compilers; this applies in particular to the first GHG inventories prepared by a country.

- **Organising and standardising data**

The data needs to be converted into a standardised format that can be processed by the tool used to estimate emissions. The activity data collected from diverse institutions are often provided in different file types, formats (e.g., different types of tables, text), and units of measure, which are not necessarily compatible with each other and/or with the software used for performing the calculations needed.

- **Estimating emissions**

Once the data has been converted into a standardised dataset, it can be used to estimate national GHG emissions. The most common method used to estimate emissions from a specific category requires multiplying the activity data collected by an **emission factor**. In some cases, the activity data needed may not be available, and it needs to be derived by applying conversion factors to proxy activity data.⁴ To estimate emissions, countries may rely on different software, including MS Excel, **MS Access**, **R**, **MySQL**, and the **IPCC Inventory Software**, and the use of more than one software can be combined.

- **Running quality checks**

It is good practice to ensure that the national GHG inventory prepared reflects certain quality standards. Therefore, during the data collection and emissions calculations processes, as well as once emissions are estimated, **quality assurance (QA)**, **quality control (QC)**, and verification

³ Further information and details on the preparation of a GHG inventory, including key steps, are presented in in Vol. 1, Chapter 1 of 2006 IPCC Guidelines for National GHG Inventories (IPCC, 2006^[2])

⁴ See (UNFCCC, 2008^[14]) for further details on how this is performed.

procedures can be run. Relevant activities also include documentation and archiving of relevant methodologies, data, communication, estimation results, reporting tables, etc (IPCC, 2006^[2]).

2.1.2. Phase Two: Reporting the GHG inventory

Once emissions are estimated, they can be organised in different formats and outputted in different file types. Further complimentary information may be added to the output file, depending on the reporting requirements established. Under the UNFCCC, national GHG inventories are part of the scope of Parties' National Communications (NCs), Biennial Update Reports (BURs), and Biennial Reports (BRs) to the UNFCCC (see (Ellis and Moarif, 2015^[7]) for further details).⁵ Annex I Parties are also required to submit annual stand-alone GHG inventory submissions, including both a National Inventory Report (NIR) and the CRF tables (UNFCCC, 2013^[3]). The NIR includes information that is essential to reporting transparent inventories, such as information on the national context, methods, assumptions, sources of data, uncertainties, time series, recalculations, planned improvements, etc. Table 1 below provides an overview of the mandatory reporting elements of national GHG inventories as outlined in Annex I and non-Annex I Parties' reporting guidelines. As indicated previously, these reporting requirements and formats vary considerably between Annex I and non-Annex I Parties, with Annex I requirements being more comprehensive.

- **Formatting the output**

To report annual GHG inventories to the UNFCCC, Annex I Parties currently use the Common Reporting Formats (CRF). These comprehensive tables are generated using a software, the CRF Reporter. Non-Annex I Parties are requested to use common, but considerably less comprehensive tabular formats in their NCs (UNFCCC, 2003^[4]), and BURs (Falduto, Wartmann and Rocha, 2020^[6]). Using formats for sectoral data that are also standardised and more comprehensive (e.g., the sectoral report tables annexed to the Revised 1996 IPCC Guidelines) is currently only encouraged for non-Annex I Parties by BUR guidelines (UNFCCC, 2012^[8]). The reporting tables are often submitted by non-Annex I Parties in a PDF format and are therefore not machine-readable.

- **Submission**

The data formatted in the appropriate tabular formats and file types are digitally transmitted to the UNFCCC or to any other national or international organisation and institution that requires the regular reporting of national GHG inventories.

Depending on the national or international framework under which GHG inventories are being reported, the data may be made publicly available. For Parties reporting under the UNFCCC, reported national inventories as part of Parties' NCs and BRs/BURs are made publicly available on the UNFCCC website⁶, in line with Article 4 of the Convention requiring GHG inventories to be published (UNFCCC, 1992^[9]). Annex I Parties' CRF tables, in particular, are made available in the form of **.xlsx** files. Numerous organisations, think tanks, and research institutions use the data included in these files for research purposes (see page 37).

⁵ Annex I of decision 24/CP.19 defines the reporting guidelines on annual GHG inventories for Annex I Parties (UNFCCC, 2013^[3]). Decisions 17/CP.8 and decision 2/CP.17 provide guidelines for the development of Non-Annex I Parties' NCs and BURs respectively, and include indications on the preparation of annual GHG inventories (UNFCCC, 2003^[4]) (UNFCCC, 2012^[15])

⁶ The UNFCCC website is available at www.unfccc.int

Table 1. Mandatory reporting elements of national GHG inventories under the UNFCCC

Reporting Element	Annex I (NIR) (decision 24/CP.19)	Non-Annex I (NC) (decision 17/CP.8)	Non-Annex I (BUR) (decision 2/CP.17)
Gas coverage	CO ₂ , CH ₄ ; N ₂ O; PFCs; HFCs; SF ₆ ; NF ₃	CO ₂ , CH ₄ ; N ₂ O (Encouraged to report PFCs; HFCs; SF ₆)	CO ₂ , CH ₄ ; N ₂ O
Years covered	Annual series, from base year to N-2	1994 or 1990 in NC1 and 2000 in NC2; LDCs can select years at their discretion. Time series not required.	At least N-4. Time series back to years previously reported, where feasible.
Frequency	Annual (by 15 April, for N-2)	Every four years (as part of the NC)	Every 2 years as part of the BUR
Common reporting format	Common Reporting Format (CRF) Tables	No requirement (Encouraged to use tables in Annex 3A.2 of IPCC GPG for LULUCF and sectoral tables from 1996 IPCC guidelines)	No requirement (Encouraged to use tables in Annex 3A.2 of IPCC GPG for LULUCF and sectoral tables from 1996 IPCC guidelines)

Note: Guidelines for BURs cross-reference guidelines for NCs.

Source: (Falduto, Wartmann and Rocha, 2020), based on (Ellis and Moarif, 2015^[7])

2.2. The CRF system

The CRF system governs Annex I Parties' reporting of inventories to the UNFCCC with regards to their final inventory estimates and supporting background information. Therefore it relates exclusively to the second phase of the inventory process mentioned above (Figure 1). Understanding how the CRF system and its key components work is particularly relevant in the context of the CRT discussions, as the CRTs are to be developed by the SBSTA "taking into account the existing [...] common reporting formats" (CRF) (UNFCCC, 2019^[5]). Two key elements constitute the CRF system: the CRF tables and the CRF Reporter software, which generates the CRF tables.

2.2.1. The CRF tables

The CRF tables are a set of tables that allow Parties to report quantitative and, to a lesser extent, qualitative data (e.g., explanations for notation keys) on national GHG inventories using a common and electronic tabular format.⁷ The CRF tables are based on the 2006 IPCC Guidelines and reflect the Guidelines' principle of ensuring that "inventory compilers can report quantitative data in a standard format and to facilitate consistency between countries, categories, gases and years" (IPCC, 2006^[2]). The CRF tables include activity-level emission data at the most disaggregated level of categories. The set of CRF tables for reporting under the Convention consists of 49 individual tables⁸, which vary in terms of structure, format, and in terms of the level of disaggregation of the information that is to be reported within them.

The CRF tables structure national GHG inventories around five sectors: Energy, Industrial Processes and Product Use (IPPU), Agriculture, Land Use, Land-use Change and Forestry (LULUCF), and Waste. CRF tables were first developed to reflect the sectors and categories of the Revised 1996 IPCC Guidelines; from 2015 onwards, Annex I Parties reported using updated CRF tables that reflected the sectoral classifications outlined in the 2006 IPCC Guidelines. However, an important difference is that while the 2006 IPCC Guidelines combine LULUCF and Agriculture into a single sector Agriculture, Forestry and Other Land Use (AFOLU), in the CRF tables, countries are to report on these separately, as two separate

⁷ Templates for the structure of the CRF tables are included in annex II to decision 24/CP.19 (UNFCCC, 2013^[3]).

⁸ Not including the reporting tables for KP LULUCF activities under the Kyoto Protocol

sectoral report tables exist for Agriculture and for LULUCF, consistently with Annex I Parties' reporting guidelines. The MPGs for the ETF also are clear that Parties must report agriculture and LULUCF as separate sectors, which is in line with the current CRF tables.⁹

The CRF tables are organised hierarchically, and information provided in the “lower-level” tables (such as sectoral background data tables) feeds into “higher-level” tables (such as summary report tables). This process is partially automated via the CRF Reporter (see page 30), and therefore Parties will not have to fill in all the 49 tables but only approximately half of these (Falduto, Wartmann and Rocha, 2020^[6]). The 49 CRF tables can be broadly grouped into four typologies, presented below from higher to lower level of disaggregation (see 4. Annex A for a full list of the 49 tables):

- **Sectoral background data tables (36 tables)**

Sectoral background data tables allow Parties to report background data and parameters that are fundamental for estimating GHG emissions for different sectoral categories and sub-categories. These include, e.g., emission activity data (e.g., annual waste amount treated) and other parameters such as operational conditions or specific national characteristics (e.g., typical animal mass of dairy cattle). The background tables automatically calculate an **implied emission factor** based on the reported activity data and emissions. Activity data and other operational parameters included in these tables are necessary to estimate national GHG emissions; without them, it would not be possible for a country to produce a national GHG inventory. Some of the information provided in sectoral background data tables feeds into the sectoral summary reports. The CRF Reporter automates this process so that a country is not required to enter the same information more than once.

- **Sectoral report tables (5 tables)**

Sectoral report tables provide a summary of GHG emissions per sector. Sectoral summary tables organise GHG emission data by category/sub-category on a gas-by-gas basis reported in mass units (kilotonnes). Data included in the sectoral report tables are, for the most part, automatically aggregated and filled in by the CRF Reporter, based on data provided in sectoral background data tables.

- **Summary report tables (3 tables)**

Summary report tables provide an overview of aggregate GHG emissions per category and sub-category on a gas-by-gas basis and as CO₂ equivalent for different GHGs using Global Warming Potential from the IPCC Fourth Assessment Report. Summary table 3 of the CRF provides an overview of methods (e.g., **tier** used) and **emission factors** used for each category and GHG. Data included in the sectoral report tables are, for the larger part, automatically filled in by the CRF Reporter, based on data provided in sectoral background data tables and in the sectoral report tables.

- **Cross-cutting tables (5 tables)**

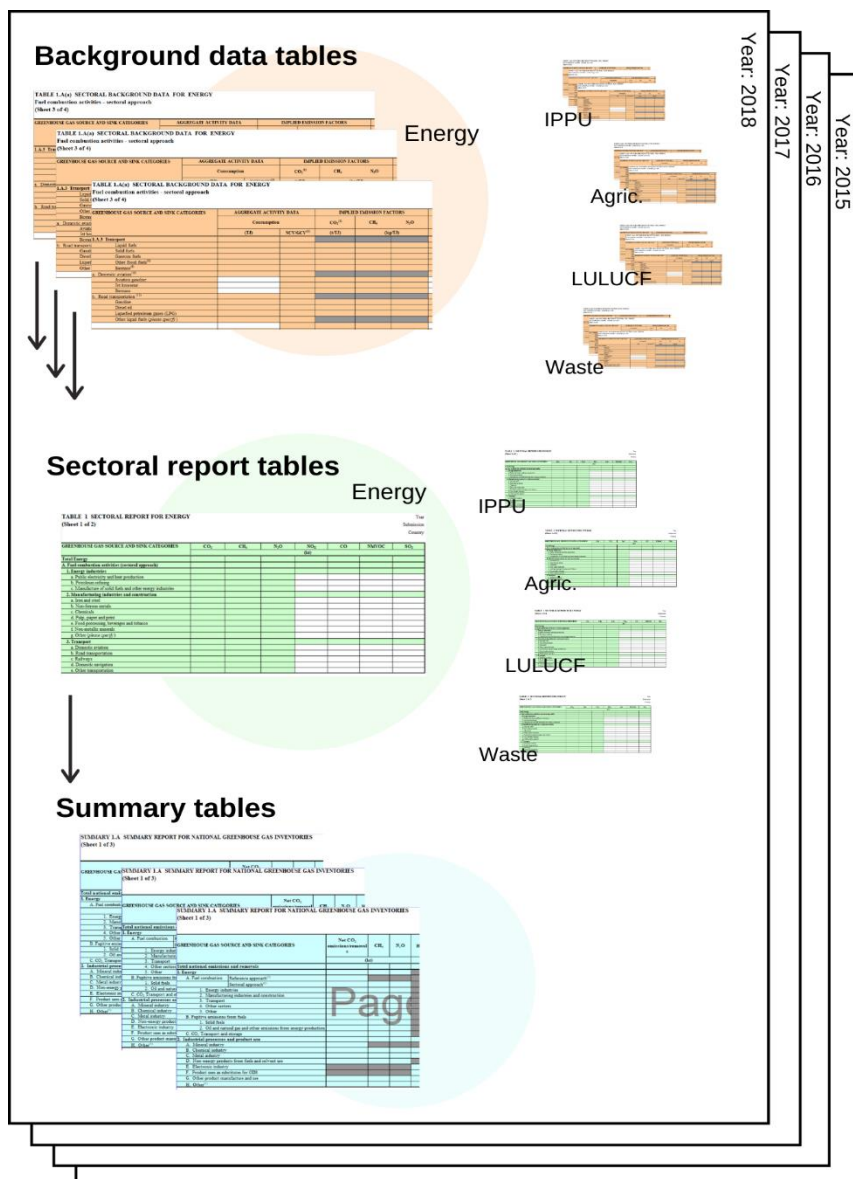
Cross-cutting tables provide other complementary information useful to the understanding of the national GHG inventory. These tables are automatically generated by the CRF Reporter based on the data filled in sectoral background data tables. These include:

- A cross-sectoral report, in which Parties provide information on indirect emissions of N₂O and CO₂ for each sector;

⁹ Paragraph 50 of the annex to decision 18/CMA.1 make it mandatory for all Parties to report the following sectors: energy, industrial processes and product use, agriculture, LULUCF and waste. Regardless of the IPCC 2006 Guidelines combining LULUCF and agriculture into a single AFOLU sector, under the ETF all Parties will report agriculture and LULUCF as separate sectors. This is further explored in (Falduto, Wartmann and Rocha, 2020^[6])

- A summary overview of **key categories**, which shows results of the key category analysis based on an approach 1 analysis with the same level of disaggregation of categories defined in the 2006 IPCC Guidelines;
- A recalculation table, which allows Parties to report on recalculated emissions per paragraphs 16-18 of the UNFCCC reporting guidelines on annual GHG inventories;
- A completeness table, which allows Parties to provide further information on the notation keys used (currently “NE”, meaning that emissions for a certain inventory category have not been estimated, and “IE”, meaning that emissions for a certain inventory category are included with the emissions of another category);
- An emissions trends table, which provides an overview of emissions trends per sector and category expressed in terms of both unit of mass (kilotonnes) and CO₂ equivalent.

Figure 2. Hierarchy of the CRF tables



Source: Authors

2.2.2. The CRF Reporter

The CRF Reporter is a web-based software developed by the UNFCCC Secretariat to facilitate the reporting of national GHG inventories by Annex I Parties. Within each Party, the number of staff with access to the CRF Reporter is usually limited. The CRF Reporter provides an interface through which Parties can report their national GHG inventories in line with the UNFCCC reporting guidelines on annual GHG inventories. The CRF Reporter's functions, therefore, only relate to the second phase (reporting) of the GHG inventory process, as it generates tables in line with the structure and format of the CRF tables annexed to decision 24/CP.19 (UNFCCC, 2013^[3]). The Reporter can also perform some basic calculation functions, including the calculation of implied emission factors, GHG emissions in CO₂ equivalent and aggregate emissions into sectoral and national totals.

The CRF Reporter generates the Party's set of CRF tables and an **XML**-file, which contains all information submitted in a fully machine-readable format. Each set of CRF tables includes a .xlsx file for each year of the time series reported (e.g., 1990-2018 for the inventories reported in 2020). Annex I Parties submit their NIRs and CRF tables through the submission module embedded within the CRF Reporter. The XML file is also provided to the UNFCCC Secretariat, where it is fed into a data warehouse system. The data warehouse system itself is not publicly accessible. Information in this data warehouse system is used for several purposes. For example, data is fed into tools facilitating the review of Annex I Parties' national GHG inventories and into the UNFCCC's GHG Data Interface (Figure 3), which presents GHG emissions reported by Annex I and non-Annex I Parties.¹⁰

Figure 3. UNFCCC GHG Data Interface

The screenshot shows the UNFCCC GHG Data Interface. At the top, there is a navigation bar with the United Nations Climate Change logo and several menu items: Time series - Annex I, Detailed data by Party, Comparison by Category, Comparison by Gas, GHG profiles, Global map - Annex I, Flexible queries, User-defined indicators, and Compilation and Accounting Data. Below the navigation bar, the 'Time Series - Annex I' section is active, showing a dropdown menu for 'GHG total without LULUCF'. Below the dropdown, there is a button 'Export to Excel' and a table of GHG emissions data. The table has columns for Party, Base year, 1990, 1995, 2000, 2005, 2010, 2017, Last Inventory Year (2018), and Change from base year to latest reported year. The data is as follows:

Party	Base year	1990	1995	2000	2005	2010	2017	Last Inventory Year (2018)	Change from base year to latest reported year
Australia	424,998.38	424,998.38	439,004.90	489,373.84	526,206.97	540,571.41	556,612.27	558,047.22	31.31%
Austria	78,492.61	78,492.61	79,382.99	80,261.99	92,427.27	84,612.84	82,023.36	78,950.34	0.58%
Belarus	137,766.41	137,766.41	81,851.22	79,588.94	86,694.06	92,278.15	91,112.50	91,992.61	-33.23%
Belgium	146,410.76	146,410.76	154,495.96	149,704.63	146,251.99	134,315.86	118,005.10	118,455.74	-19.09%
Bulgaria	116,754.51	101,794.34	74,614.54	59,580.03	64,117.73	60,726.73	61,682.76	57,815.59	-50.48%
Canada	603,221.87	603,221.87	653,057.98	730,681.59	729,747.17	690,530.62	713,838.21	729,349.27	20.91%
Croatia	31,875.85	31,875.85	22,739.43	25,708.82	29,920.38	28,033.73	25,032.08	23,792.80	-25.36%
Cyprus	5,690.44	5,690.44	7,143.86	8,457.56	9,390.60	9,518.12	8,974.40	8,811.61	54.85%
Czechia	197,202.55	197,202.55	156,526.03	149,457.61	147,905.91	139,900.21	129,059.00	127,449.60	-35.37%

Source: UNFCCC Greenhouse gas inventory data, available at https://di.unfccc.int/time_series

¹⁰ Data from non-Annex I Parties are presented in the following modules of the data interface: (i) Detailed data by Party; (ii) Comparison by category/gas; (iii) GHG profiles; (iv) Flexible queries; (v) User defined indicators. The Flexible Queries module of the data interface presents GHG emissions data, activity data, implied emission factor, method and emission factor information.

Data entry and automatic filling in of tables

Data entry into the CRF Reporter is possible in three main ways. Firstly, users of the software can enter relevant data manually into the software itself. Some information (e.g., numeric data and notation keys) is typed in manually, whereas other information (e.g., the method used to estimate emissions) can be selected from a drop-down menu. This approach is illustrated in Box 2. A second option is that of exporting empty tables from the CRF Reporter into .xlsx format, filling in relevant data into the .xlsx file, and uploading it back into the CRF Reporter. This approach is illustrated in Box 3. A third, more efficient, option is that of directly importing a pre-compiled XML-file with the relevant data into the CRF Reporter. Most Annex I Parties have developed national systems that, after the national GHG inventory has been compiled, generate a CRF-compatible XML-file for this purpose. This approach is further explored at page 34.

Data entry into the CRF Reporter is further facilitated by a number of data-entry functions offered by the software. Key functions include:

- **Automatic filling in of tables**

While the CRF Reporter generates a large number of data tables, most of them do not have to be filled in by the users of the software themselves. Parties are able to insert data (e.g., GHG emissions and activity data) manually in a limited number of white-coloured cells. This applies to all sectors. In background data tables, some values are automatically calculated based on other information filled into the software, e.g., implied emission factors (see Box 4). Summary tables, sectoral summary tables, and some cross-cutting tables are mostly populated automatically drawing from data included in, e.g., background data tables (see Box 5). These are indicated by green (for sectoral summary tables) or blue (summary and cross-cutting tables) cells. The automatic completion of tables is based on a bottom-up approach, aggregating GHG emissions filled in by the user at the category level as appropriate for the sectoral report tables and the summary tables. In very limited cases, in background tables, Parties may find a need to overwrite some green shaded cells, for example, to mask confidential data. This procedure would need particular caution to ensure that reporting does not become less transparent (e.g., relevant information could be included in the documentation box to explain a Party's reporting). The overwritten cells are marked as pink cells.

- **Inclusion of extra categories**

For most categories, Parties are allowed to manually add and name country-specific sub-categories, which would then be reflected in the exported CRF tables. These are marked by an orange highlight in the navigation tree.

- **Completion of documentation boxes**

The CRF Reporter allows for the provision of comments to a given category or sub-category that apply to all or some reporting years to be reflected in the documentation box of the corresponding table.

- **Automatic propagation of notation keys**

Any notation keys entered in the data entry grids will automatically be propagated in the subsequent columns (i.e., years).

Box 2. In practice: Manually entering data into the CRF Reporter

Figure 4 shows the CRF Reporter’s data entry fields for category 2.A.1 Cement production, with data entered for the year 1990 marked by the red boxes. Data to be entered manually includes activity data and total emissions per year per gas. In the case of cement, the type of activity data has to be specified (e.g., clinker production). The CRF Reporter automatically calculates the implied emission factor based on activity data and total emissions. The tiers used for activity data and emission factors have to be specified by selecting the appropriate label through a drop-down menu. Explanatory text can be typed into the appropriate documentation box.

Figure 4. Manual data entry for category 2.A.1 Cement production

Administration		Inventories	Data Entry	Reporting Tables	Import / Export	Data Checks	Useful Links	
Sectors/Totals / 2. Industrial Processes and Product Use / 2.A Mineral Industry / 2.A.1 Cement Production								
Navigation Tree								
Sectors/Totals								
1. Energy								
2. Industrial Processes and Product Use								
2.A Mineral Industry								
2.A.1 Cement Production								
2.A.2 Lime Production								
2.A.3 Glass production								
2.A.4 Other Process Uses of Carbonates								
2.B Chemical Industry								
2.C Metal Industry								
2.D Non-energy Products from Fuels and Solvent Use								
2.E Electronics Industry								
2.F Product Uses as Substitutes for ODS								
2.G Other Product Manufacture and Use								
2.H Other (please specify)								
3. Agriculture								
Node								
Node comment								
Node year								
Id	[2. Industrial Processes and Product Use][2.A Mineral Industry][2.A.1 Cement Production]	Unit	1990	1991	1992	1993	1994	1995
L2	Clinker production	kt	1,000.00					
L4	CO2		T1					
L6	CO2		D					
L8	CO2	kt	520.00					
L13	CO2	kt						
L13	CO2	kt	0.52					
L14	Documentation box							

Source: Authors

Box 3. In practice: Importing data from an MS Excel sheet into the CRF Reporter

This data entry form allows downloading the data entry grids in MS Excel format from the CRF Reporter and allows working offline. To import data from a MS Excel sheet, a CRF .xlsx template is first downloaded from the CRF Reporter, filled in manually with appropriate data as shown in Figure 6, and imported back into the CRF Reporter. Once the file is imported into the CRF Reporter, the tool will automatically fill in the appropriate data entry fields, as shown in Figure 5 above. Implied emission factors will be automatically calculated.

Figure 5. Data import sheet for category 2.A.1 Cement production, filled with regards to CO₂ emissions in the year 1990

[2. Industrial Processes and Product Use][2.A Mineral Industry][2.A.1 Cement Production]					
[2. Industrial Processes and Product Unit]		1990	1991	1992	1993
Activity data					
Clinker production	kt	1000.00			
Method					
CO2		T1			
Emission factor information					
CO2		D			
Emissions					
CO2	kt	520.00			
SO2	kt				
Recovery					
CO2	kt				
Implied emission factor					
CO2	t/t				
Documentation box					

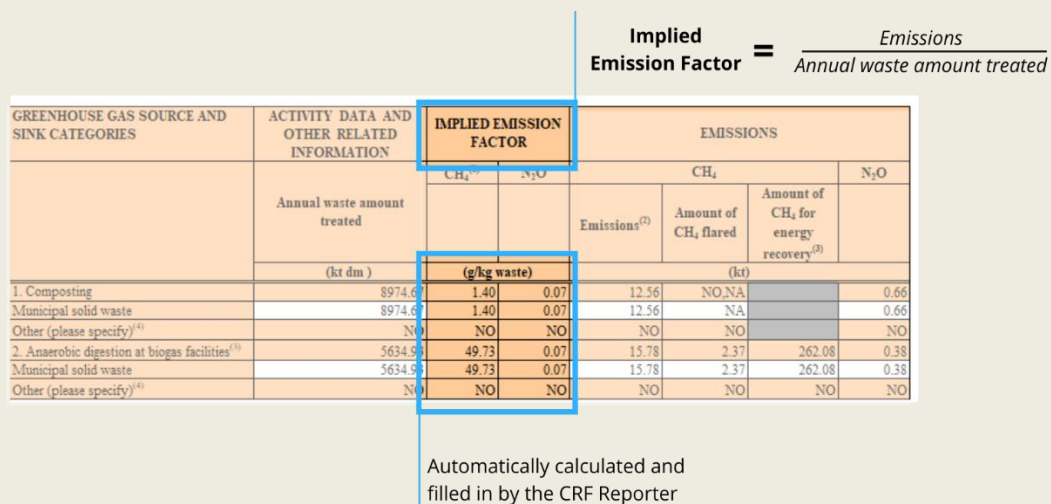
Source: Authors

Box 4. In practice: Filling in the background data tables

The background data tables require the filling in of detailed information on, e.g., activity data and emissions. The level of detail of the information to be provided in sectoral background data tables may depend on a country’s reporting capacity, as it can be related to the **Tier** chosen by a country to estimate emissions. Often, the higher the tier adopted to estimate GHG emissions, the more background data are needed to calculate emissions before entering data in the CRF Reporter. Sometimes, the use of higher Tiers will be reflected with the need to include more detailed information in the background data tables. For example, a country reporting on dairy cattle CH₄ emissions using Tier 1, will only need background data information on population size and allocation per climate region. A country that uses Tiers 2 or 3 will need specific data on manure characteristics such as volatile solids daily excretion. (IPCC, 2006^[2]) In other cases, the tier chosen will not affect the detail of information that is to be included in the background data tables. For example, national activity data may be based on the sum of plant-specific data for ammonia production facilities for a higher tier and national production statistics for Tier 1, but in both cases, a single value for activity data is entered into CRF table2(I).A-Hs1).

The CRF Reporter further facilitates the filling in of the CRF tables by automatically calculating implied emission factors. Implied emission factors are instrumental when comparing GHG-inventory data across different countries, for example, for quality control purposes. Emission factors can usually be found in the existing literature. Countries using a high Tier may use their own peer-reviewed literature, as it can provide parameters that are tailored to specific national circumstances and context. Countries using lower Tiers (e.g., Tier 1) can rely on the IPCC default emission factors. While a Party would need to use emission factors to calculate its emissions, at the time of reporting through the CRF tables, implied emission factors presented in the background data tables are automatically calculated by the CRF Reporter upon Party’s provision of activity data and GHG emissions (see Figure 6). These may be different than the actual emission factors used to estimate GHG emissions.

Figure 6. Implied emission factors in CRF tables



Note: To note that GHG emissions in sectoral background data tables are expressed in kilotonnes.
Source: Authors.

Box 5. In practice: Automatic filling in of higher-level tables

Based on the information provided in the data entry fields of the background data tables, the sectoral report tables and summary tables are automatically populated with aggregated data. Figure 7 shows, as an example, how emission values provided in the background data table for IPPU are automatically aggregated and filled in in the IPPU sectoral report and the emissions trends summary table.

Figure 7. Example of automatic filling in of higher-level tables

Background data
Emission values in white cells are filled in by the user, and the aggregate value is automatically calculated

TABLE 2(D)-A-H SECTORAL BACKGROUND DATA FOR INDUSTRIAL PROCESSES AND PRODUCT USE
Emissions of CO₂, CH₄ and N₂O
(Sheet 1 of 2)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA		IMPLIED EMISSION FACTORS ⁽¹⁾			Emissions ⁽²⁾
	Production/Consumption quantity		CO ₂	CH ₄	N ₂ O	
	Description ⁽³⁾	(kt)				
A. Mineral industry				0.0		1270.00
1. Cement production	Clinker production	1000.00	0.52			520.00
2. Lime production	Lime production	1000.00	0.75			750.00
3. Glass production						
4. Other process uses of carbonates						
a. Ceramics						
b. Other uses of soda ash						
c. Non-ferrous metal production						
d. Other						

Sectoral report
All the values in the sectoral report tables are automatically filled in by the CRF Reporter

TABLE 2(I) SECTORAL REPORT FOR INDUSTRIAL PROCESSES AND PRODUCT USE
(Sheet 1 of 2)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO ₂	CH ₄	N ₂ O	HFCs ⁽¹⁾	PFCs ⁽¹⁾	Unspecified mix of HFCs and PFCs ⁽¹⁾
	(kt)					
CO ₂ equivalent (kt)						
Total industrial processes	1270.00					
A. Mineral industry	1270.00					
1. Cement production	520.00					
2. Lime production	750.00					
3. Glass production						
4. Other process uses of carbonates						
B. Chemical industry						
1. Ammonia production						
2. Nitric acid production						

Emission trends
All the values in the emission trends table are automatically filled in by the CRF Reporter

TABLE 10 EMISSION TRENDS
GHG CO₂ eq emissions
(Sheet 1 of 6)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year ⁽¹⁾	1990
	(kt CO ₂ eq)	
Total (net emissions) ⁽²⁾	1270.00	1270.00
1. Energy		
A. Fuel combustion (sectoral approach)		
1. Energy industries		
2. Manufacturing industries and construction		
3. Transport		
4. Other sectors		
5. Other		
B. Fugitive emissions from fuels		
1. Solid fuels		
2. Oil and natural gas and other emissions from energy		
C. CO ₂ transport and storage		
2. Industrial Processes	1270.00	1270.00
A. Mineral industry	1270.00	1270.00
B. Chemical industry		
C. Metal industry		

Source: Authors

Notably, the CRF Reporter allows for the storage of multiple versions of Parties' submissions¹¹, and it also carries out some QA/QC checks on the data provided. The quality assurance function of the CRF Reporter includes several tools. Among others, the completeness check verifies that all required data has been entered. The consistency check allows users to update all the calculated values in a given year.

2.3. IT arrangements and software can facilitate CRF-reporting

Setting up an efficient national IT system and identifying the appropriate tools to produce the GHG estimates and store the data is fundamental to minimise the time and the resources needed to implement the reporting under the CRF system. To report national inventories via the CRF system, GHG data needs to be calculated first. An efficient IT setup for the preparation of the national GHG inventory can significantly facilitate CRF-reporting by directly inputting relevant data into the CRF Reporter, avoiding the need to input GHG emissions into the software manually.

There are different tools and software that can allow countries to manage their national GHG inventories and to calculate national GHG emissions starting from activity data and emission factors. As countries have very diverse levels of technical and reporting capacity, availability of resources including IT hardware and software, and other national circumstances including internet connectivity and access, it is for each country to understand what tools and software can render its inventory process more effective and efficient and how these might need to be adapted over time to consider changing needs and facilitate continuous improvement.

2.3.1. Main tools and software used to prepare national inventories: Experience from Parties

The IT arrangements and software used by countries to prepare their national GHG inventories differ significantly among countries. Annex I Parties, which have long-standing experience in reporting national GHG inventories annually, use a diverse range of tools, and only a few use a fully tailored software solution. Typically, commonly-used software programs are used (e.g., MS Excel, MS Access, and MySQL) and often combined to make the best use of their specific functionality, e.g., the ability to be flexibly amended, to store large amounts of data, perform complex data manipulation, etc. GHG inventory compilation teams appreciate software solutions that inventory experts are already familiar with and that can be easily adjusted where needs change over time. Current countries' experience in preparing national GHG inventories shows that many countries favour the use of MS Excel. This is because of Excel's intuitive user interface and wide-spread use. MS Excel is also deemed to be a rather versatile tool that can allow compilers to easily change the structure of the database and inventory if needed.

The following subsection presents tools and approaches used by four Parties and one regional group in preparing and reporting their national GHG inventories. While Lebanon is not an Annex I Party and does not report using the CRF Reporter, its experience in setting up a system in a step-wise and adjustable manner that could be compatible with a CRT system might be helpful to other Parties.

United Kingdom

The United Kingdom (UK) uses a combination of software tools, including MS Excel, MS Access, R, and MySQL. The tools used are selected to provide the best functionality for the various tasks in the GHG inventory compilation process and have changed over time. Instead of building one comprehensive software tool, the UK GHG inventory compilation team prefers a more elastic approach, which allows the

¹¹ If this function is retained in a CRT Reporter, it would support archiving of all information for the reported time series as addressed by paragraph 19(c) of the MPGs (UNFCCC, 2019^[5]).

inclusion of new tools and software as they become available. Once collected, activity data and emission factors are cleaned and structured in so-called “master sheets” in MS Excel. In the past, the master sheets were uploaded into MS Access, where the GHG estimation and other calculations took place. As the allowed size of MS Access databases is limited, calculations had to be performed through multiple databases. For this reason, the inventory team decided to migrate to MySQL, which is better suited for complex calculations and storage of large amounts of data. To make the best use of existing processes while adding improved functionality, MS Access and MySQL were combined: the activity data and emission factors in the Excel master sheets are still uploaded into MS Access but are then transferred into a MySQL database where calculations take place and data is stored. R is used, among other software, to change the structure of large datasets, e.g., to change energy statistics provided in Excel into a format that can be uploaded into the database.

The database contains a table that specifies how each activity data and emission factor data point relates to each GHG inventory category. This allows for the easy assignment of the GHG emissions calculated from each combination of activity data and emission factor to a GHG inventory category. This is the basis for reporting into the CRF Reporter format. The reporting itself is carried out using Excel and a Visual Basic script to generate an XML file that is uploaded into the CRF Reporter. The script matches the data required by the CRF-Reporter to the data in the database. This information is checked manually and adjusted as necessary before the inventory is submitted.

Lebanon

Lebanon has developed a web-based system called Management Information System on Climate Action (MISCA). The system will, in the long-term, support all areas of NDC-tracking, including GHG inventory, mitigation actions, support, etc. The development of the system is ongoing, and required functionalities are added in a step-wise manner. This is facilitated by the system being easily adjustable. In 2016, MISCA focused on collecting energy data, including power generation and power plants' fuel consumption. This information, combined with the IPCC default emission factors, allowed for the calculation of GHG inventory data related to power and heat production. Later, a function that enabled the automatic calculation of a grid factor was added. This upgrade allowed for the estimation of GHG reductions for specific mitigation actions related to power generation, for example, renewable energy projects. At present, the MISCA focuses on the energy sector.

Data is entered through a web interface by staff at the Ministry of Energy and Water, Électricité du Liban (EDL), and other stakeholders trained for data entry. Three tiers of responsibility have been defined for data entry: data collector, data validator, and data releaser. Data can be outputted in both graphic and tabular formats. GHG inventory data is currently outputted in the tabular format requested by UNFCCC Decision 17/CP.8 for National Communications of non-Annex I Parties. In the long-term, the system will be updated to provide GHG inventory data in the yet-to-be-agreed CRTs for BTRs. Lebanon plans to extend MISCA in 2021 to offer data collection and calculation for the IPPU and the agriculture sectors. The inclusion of waste and LULUCF is currently not planned, given the complexity of data collection and calculation in these sectors.

Several lessons learned have already been identified. When MISCA was first developed, a developer's close cooperation with a GHG inventory expert and an energy sector expert allowed a comprehensive understanding of required functionality, data availability, and stakeholder abilities and needs. A cloud-based solution was not considered acceptable in the long-term due to data security concerns, so that a server-based solution will be sought in the future.

France

France uses a combination of standard software tools, including MS Excel and MS Access. Once collected, cleaned GHG data is compiled in sectoral MS Excel files and uploaded into a centralised MS Access

database, where the calculations take place, and the data are stored. Similarly to the UK, the combination of several tools is preferable as it is considered more adjustable and cost-effective than the development of one comprehensive, tailored system. MS Excel is valued for the flexibility it provides and because sectoral GHG inventory experts are familiar with the tool. Using MS Access for calculation and data storage is feasible for France's national-level GHG inventory despite MS Access databases' limitations. However, where GHG inventory compilation has to consider additional data, e.g., to compile GHG inventories at the city level, a tool that can accommodate larger datasets would be required. The XML file for upload to the CRF Reporter is generated from the access database. A separate Reporter tool based on MS Access generates tables in the same format as the CRF Reporter. These tables can then be used for early reporting and are compared to the CRF-tables generated by the CRF Reporter for quality control purposes.

The Technical Reference Centre for Air Pollution and Climate Change (CITEPA), which operates France's national GHG inventory system, has helped some developing countries set up similar systems. These are stand-alone (MS Access application and database) or web-based systems (Drupal developments with Postgres database), where Excel files with data can be uploaded for calculation and storage and/or archiving. The systems include quality control functions, e.g., for data review and data approval, as well as differentiated user profiles, so users can only manage and/or see data related to their specific profile. The system outputs GHG inventory data in the tabular reporting formats requested for NCs and BURs.

Japan

Japan uses MS Excel for the majority of its GHG inventory preparation. To collect GHG inventory activity data and to produce estimates, Japan has developed calculation MS Excel spreadsheets, which are categorised into five hierarchical levels (see Figure 8):

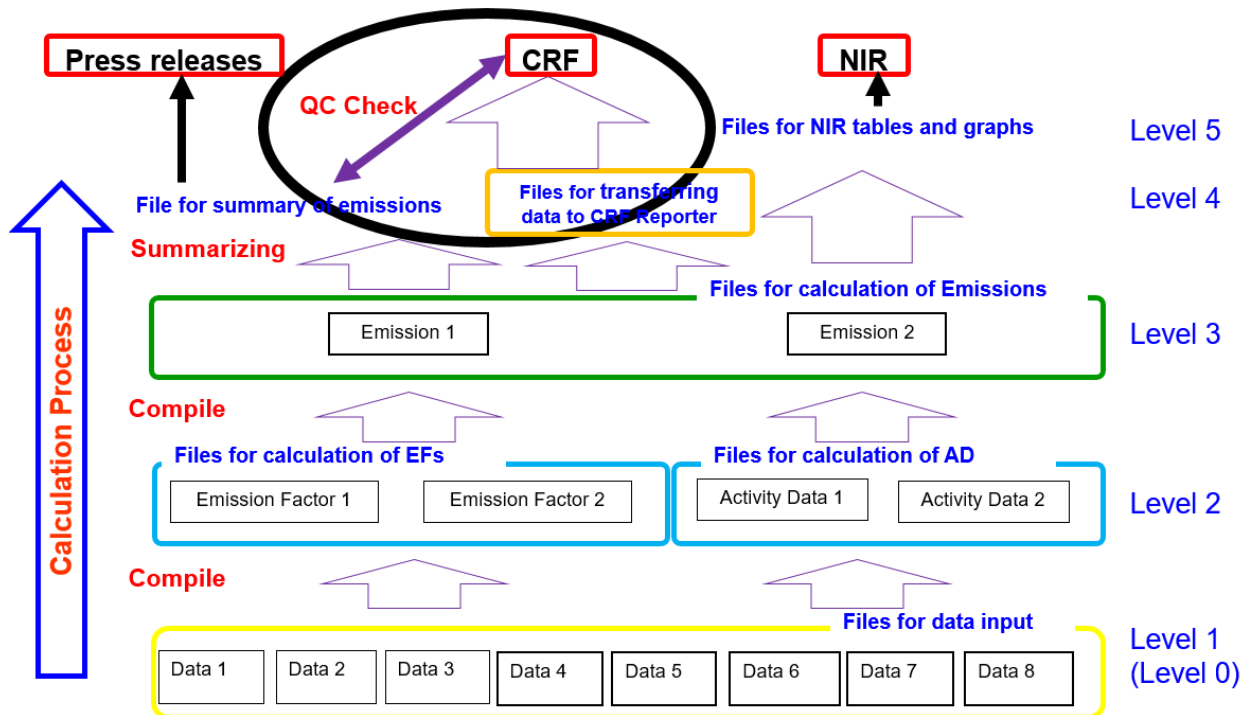
- Level 0: Original data from data providers
- Level 1: Files for data input
- Level 2: Files for calculation of emission factors and activity data
- Level 3: Files for calculation of emissions
- Level 4: Files for a summary of emissions/QC check and transferring data to the CRF Reporter
- Level 5: Files for output to NIR tables and graphs

Level 0 spreadsheets and files include raw data received from relevant ministries, agencies, and other data providers; these are stored in the same format as they were received in. Levels 1 through 5 include a total of 330 files. Spreadsheets from Level 1 to 3 are designed to look similar to the Excel data entry sheets of the CRF Reporter and present, to the extent possible, the same format across all sectors. This facilitates data entry and reduces errors. All calculations to produce estimates and other data are automatically carried out in Excel through the calculations spreadsheets. To facilitate the consultation and use of these spreadsheets, Japan has developed a methodology to name the calculation files. In particular, these indicate the category number, the level, and the submission year, e.g., "1B-L3-2020" corresponding to the calculation file of the emissions from the 1B category (fugitive emissions from fuels) prepared for the 2020 submission. Level 4 files for transferring data to the CRF Reporter include links to Level 3 files to calculate emissions. This means that, once emissions have been calculated, the Level 4 files are filled in automatically. The necessary links have been set-up manually once and are now simply updated for each new submission. This is done by first Exporting new 'blank' Excel files from the CRF Reporter and copying in the links from the previous set of L4 files, and updating the links to the L3 files. The links are cut off just before upload into the CRF Reporter, as this avoids rounding issues. Each calculation file covers the entire inventory time-series, facilitating quality control by the compilers, as trends can be easily analysed.

In Japan's experience, MS Excel has proven to be an optimal tool for implementing the inventory process. This is because MS Excel is considered to be a reasonably easy-to-use software with a user-friendly

interface; further, its widespread use ensures that newcomers already have some experience with the software, therefore, facilitating their familiarisation process, without the need of specialised training.

Figure 8. Overview of Japan's MS Excel file system



Source: (Hatanaka, 2021^[10])

Latin American GHG inventory network

The Latin American GHG inventory network (“Red INGEI”) was formed in 2013 and includes 15 Latin American countries. These countries co-operate in developing their national GHG inventories, e.g., through experience exchange and mutual reviews. The network has developed an Excel-based reporting format, based on the CRF tables used by Annex I parties. This emanated from the desire to use a common reporting format based on the IPCC 2006 Guidelines and to support progress towards Annex I reporting processes over time.

The common reporting format developed by Red INGEI enhances comparability among the GHG inventory data reported by the members of the networks and facilitates review. The MS Excel spreadsheets are based on the CRF summary tables and include one spreadsheet for each reporting year. Summaries are presented by CO₂-eq and by gas on separate sheets each. Background data tables have not yet been included. The files also include different sets of GWPs, which allow each country to choose an appropriate set according to national circumstances. Furthermore, the files offer simple quality control functions, including generating graphics, performing comparison calculations, and presenting spark lines.

While a common reporting format is used, each country uses its own MS Excel worksheets to produce GHG estimates. These MS Excel calculation files are then manually linked to the common reporting format. This procedure can be quite time-consuming the first time; however, for subsequent reports, the links can be easily updated every year. To further facilitate comparability across countries, the network has also developed a standardised NIR reporting format in MS Word. The reporting format foresees an executive summary, which can be used as the GHG inventory section for the BUR.

2.3.2. Other tools and software that could facilitate CRF reporting

To date, there is no publicly- and readily-available software that is specifically designed for GHG-inventory compilation to assist countries through all the steps of the inventory process and feed information directly into the CRF Reporter. Most Annex I Parties use commonly-available commercial or open-source software to prepare national GHG inventories and produce files readable by the CRF Reporter, primarily, as highlighted above, using hybrid systems which can be more easily adjusted to national circumstances. Nevertheless, there are a number of software programs that are either under development or that have potential for further development to assist countries throughout the inventory process and output inventory data in CRF-Reporter-readable format. Some of these software and tools are free (e.g., the IPCC Inventory Software by the IPCC, the ALU Software by the University of Colorado), others are commercial (e.g., Atmo by Spherical). Of these, the IPCC Inventory Software is the most widely used.

The IPCC Inventory Software

The IPCC Inventory Software¹² is a free MS Access-based software programme to assist countries in both estimating and reporting data on national GHG emissions. The software was produced in 2012 by the IPCC Task Force on National Greenhouse Gas Inventories. To date, it has been used primarily by non-Annex I Parties for the preparation of their NCs and BURs, as it allows for the export of reporting tables that are consistent with the format and structure of the tables that Non-Annex I Parties are requested to use in their NCs, and that are contained in the Annex to decision 17/CP.8 (UNFCCC, 2003^[4]).

The IPCC Inventory Software implements the 2006 IPCC Guidelines for the estimation of GHG emissions. It allows for the application of Tier 1 estimation methods for all sectors and Tier 2 methods for most categories of Energy, IPPU, Agriculture, and Waste. Multi-Tier inventory preparation is supported, whereby different tiers can be used for different sectors or categories. To estimate GHG emissions using Tier 1 methods, the IPCC Inventory Software incorporates default emission factors from the 2006 IPCC Guidelines.

The basic layout of the IPCC Inventory Software's working area consists of a worksheet grid that allows the inventory compiler to fill in and edit, as appropriate, activity and emission factor data for each category and sub-category (Figure 9). When applicable, the user will select the tier of interest that will apply to the worksheet. To provide information on activity data, a user can either type in a numeric value or chose a notation key from a drop-down menu among IE ("included elsewhere"), NO ("not occurring"), or C ("confidential").¹³ Emission factors can either be selected through a drop-down menu, which offers default values, or can be inserted manually as custom values by the user. Upon selecting or manual entry of the emission factor and activity data, emissions are automatically calculated and filled in in the appropriate cells. Within the working area, a small window provides information from the 2006 IPCC Guidelines related to the category selected.

The IPCC Inventory Software supports functions related to the management and administration of data and allows QA/QC checks, uncertainty and key category analysis, value check, and reporting of the reference approach. The Software can also be used to store and archive data, as it can produce an MDB file (i.e., an MS Access database file), and it offers a backup function. Once the inventory is finalised, inventory data, including sectoral worksheets, can be exported as an XML file and non-Annex I Parties'

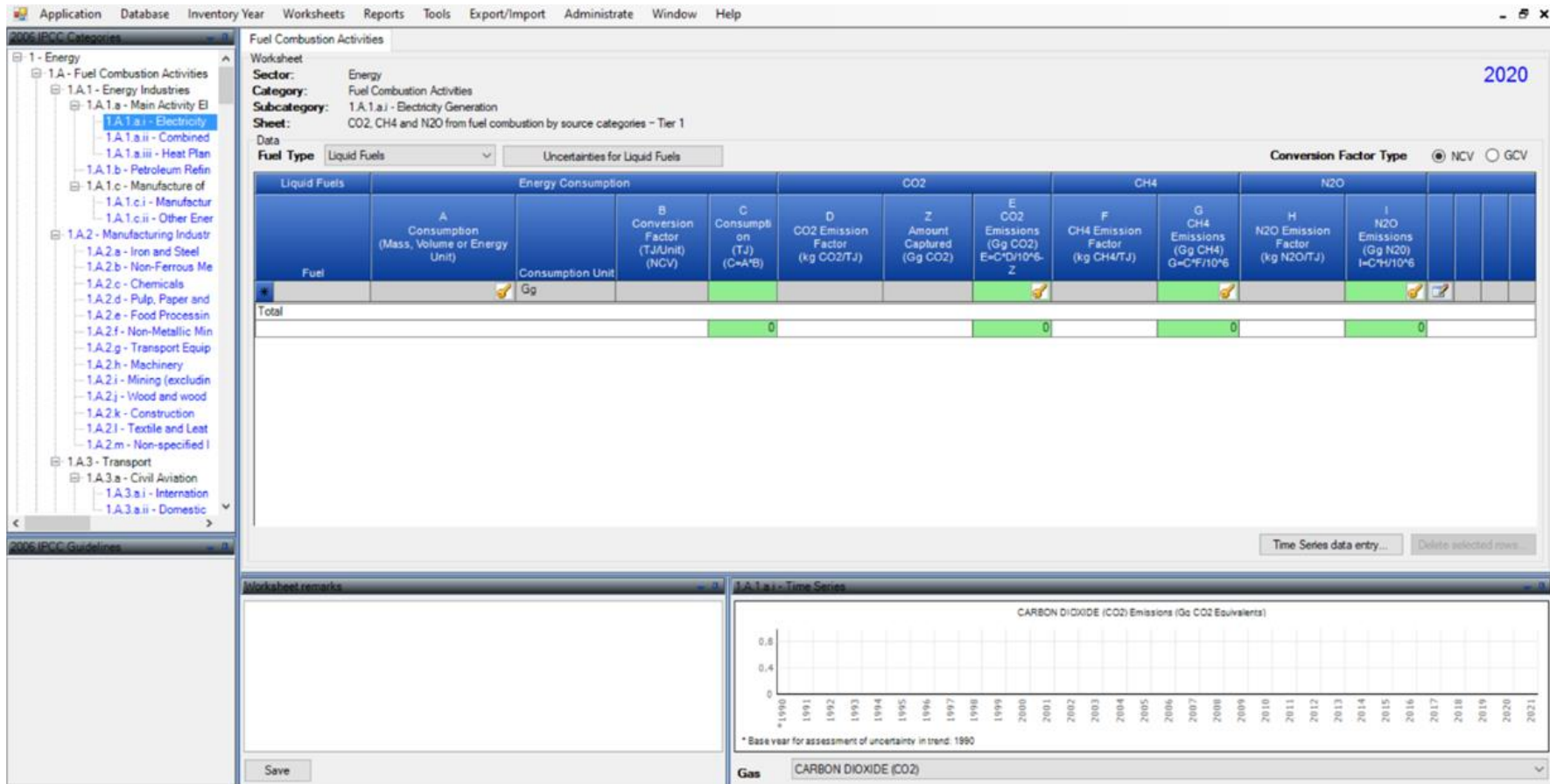
¹² More information on the software and a link to download the software can be found on the following site: <https://www.ipcc-nggip.iges.or.jp/software/index.html>.

¹³ When the IE or the NO notation keys are used, all "activity data" and "emission factor" cells of the row are left empty and locked for editing. When the C notation key is used, the data will appear in the worksheet but will not be exposed in the reporting tables but only included at the aggregate level.

reporting tables as .xlsx. There are also options to export CO₂ equivalents and F-Gases data as XML files specifically.

The IPCC Inventory Software holds potential for improvement. Depending on future availability of resources, the IPCC has communicated its plan of improving the Software by implementing all of the IPCC Tier 2 and 3 methods provided by the 2006 IPCC Guidelines and the Wetlands Supplement; allowing the application of Tier 2 for the Uncertainty and Key category analysis and allowing for the export and import of time series, which could be useful for CRT-reporting.

Figure 9. Working area of the IPCC Inventory Software



Source: Authors

Unclassified

2.4. Domestic and international uses of CRF tables

Once submitted to the UNFCCC, CRF data are used for several processes, for example, for domestic policy-making or research activities and as part of the technical review process under the UNFCCC. This subsection presents experiences from these processes in using CRF data, its benefits as well as limitations. Understanding how CRF data are used helps understand how new tables could be improved to ensure that the purpose of the tables –that is, providing information on Parties' GHG emissions in a clear, transparent, and comparable format—is maximised. This sub-section outlines a couple of examples of CRF tables.

2.4.1. Facilitate the UNFCCC technical review

National GHG inventories submitted by Annex I Parties are reviewed under the UNFCCC, as per decision 19/CP.8 (UNFCCC, 2003^[11]). The main purpose of the review, according to decision 13/CP.20 is, among other things, to “assist Annex I Parties in improving their reporting of information contained in GHG inventories” and to ensure that the “Conference of the Parties (COP) has accurate, consistent and relevant information in order to review the implementation of the Convention” (UNFCCC, 2015^[12]). Over the years, the review process has greatly enhanced the improved quality of GHG inventories submitted by Parties. In theory, the more transparently information is reported, the easier it is to review. A common reporting format greatly contributes to such transparency, as reviewers will know where to look for which information, and it also enables the reproduction of estimates. The reviews' efficiency can be further enhanced where tools can be used to conduct automated checks and present data in other formats or graphically. For example, analysing trends and comparing GHG inventory data and IPCC default parameters (including emission factors) with those of other countries' data are among the most relevant approaches when reviewing national GHG inventories. The current CRF only presents GHG emissions trends (total CO₂-eq for all gases, kt per gas) and only at higher levels of aggregation. Trends are not presented for CO₂-eq per gas, activity data, and emission and other factors.

To help facilitate the technical review task, the UNFCCC Secretariat has developed tools that allow reviewers to easily analyse and compare trends for all relevant calculation data and emission values both over time and between countries (called the Locator Tool) as well as to compare emission values where recalculations have taken place (called the Comparison Tool). These tools are fed from the UNFCCC Secretariat's data warehouse, which in turn is provided by the (machine-readable) XML files submitted by Parties as part of their GHG inventory reporting.

2.4.2. Facilitate the usability of the reporting tables

Emission data included in CRF tables constitute a crucial primary emission dataset for academia, organisations, and institutions, as it contains data reported directly by countries that are publicly available in the form of MS Excel (.xlsx) files on the UNFCCC website. Furthermore, such data can be particularly relevant at the national level, as it can support policy- and decision-makers by informing the development and implementation of national policies and strategies. For these reasons, there is value in ensuring that the reporting tables are designed to facilitate consultation and elaboration of data they contain.

In practice, data organised in a set of CRF tables whose structure is common across all Annex I Parties greatly facilitates the machine-readability of the data and allows for easy comparability of GHG emissions across different countries. However, experience from institutions that currently work with the CRF tables highlights that there is potential for improvement. The specific formatting of the .xlsx files generated by the CRF Reporter can render a comprehensive and automated analysis of data quite cumbersome. For example, having one common heading for several columns may render automated machine-readability of

the sheets difficult. Considering that 44 Annex I Parties have been communicating CRF tables since 2003¹⁴ and that each CRF submission contains multiple MS Excel files of approximately 71 spreadsheets each, the complete CRF dataset as of 2020 is spread across nearly 1500 Excel files for a total of more than 128000 spreadsheets. Such a large number of files render data processing difficult and time-consuming for researchers and other organisations that may use data included in CRF tables to produce analysis.

Furthermore, recent experience suggests that the diverse structure of the different typologies of CRF tables render automated processing rather complex. Currently, a different script may be needed to read each of the 78 spreadsheets that constitute a set of CRF tables, and data fields, headers, and the number of rows and columns vary considerably across the tables. These scripts need to be manually updated for any change to the CRF table, which requires significant effort by researchers and other users. Updates could be dealt with more efficiently if a machine-readable version of the data was provided. Other minor differences in the standardised structure of the tables across countries due to Parties' reporting of "other" categories also renders automated processing of information more difficult. This, together with the use of documentation boxes to provide key explanatory information in a textual format require manual checks by the analysts.

¹⁴ To note that not all 44 Annex I Parties have been reporting CRF tables since 2003; for simplification purposes, this factor is not taken into account here.

3. Looking ahead: Designing functional CRTs and their related software

With the ETF, for the first time, a set of tabular formats for the reporting of GHG inventories will be common to *all* Parties of the Paris Agreement. As such, it is crucial that the CRTs allow for the transparent and rigorous reporting of emissions in line with the MPGs, particularly reflecting the specific flexibility provisions relevant to the design of the CRTs and available to those developing countries that need them in the light of their capacities. The analysis in the previous section underlines that, in order to enhance transparency and minimise effort in reporting and using GHG inventory data, the relationship between the CRF tables and the CRF Reporter as well as the data formats generated is important. This section outlines a set of annotated questions that can provide food for thought to delegates in the context of the transparency negotiations held under the SBSTA, focussing mainly on the relation of CRTs and the CRT Reporter. A synopsis of the informal consultations held to date is reflected in the SBSTA informal note by the co-facilitators under their own responsibility (UNFCCC, 2019^[13]). Previous CCXG analysis (Falduto, Wartmann and Rocha, 2020^[6]) offers a more in-depth assessment of concrete CRT options currently being discussed in the negotiations.

3.1. Which CRF tables are necessary/relevant for the reporting of national GHG inventories, and do existing CTF tables offer opportunities for improvement?

All the CRF tables currently in use provide important GHG inventory information and, therefore, could be considered for inclusion in the set of CRTs. In the context of the UNFCCC transparency negotiations on the development of CRTs, a minority of Parties is of the view that the set of CRTs could be simplified compared to the current set of CTFs, and that some of the existing tables could be excluded. Yet, this paper shows that excluding the automatically generated tables, for example, would not necessarily reduce Parties' reporting burden because the data entry and automatic filling in functions of the current CRF Reporter significantly limit the amount of data that actually needs to be manually filled in by Parties. Similarly, excluding the background data tables will not affect the data acquisition burden and will not significantly reduce reporting burden because such tables require the provision of activity data needed to estimate emissions in the first place. In practice, obtaining activity data to estimate emissions can be one of the most challenging steps of GHG inventory preparation. If data are unavailable, this could be reflected in the background tables through other approaches, e.g., the use of notation keys. Overall, the suggestion of reducing the number of tables to be included in the set of CRTs compared to the current set of CRF tables would work against the MPGs' principle of "ensuring that Parties maintain at least the frequency and quality of reporting in accordance with their respective obligations under the Convention" (Annex to decision 18/CMA.1, Section I, §3.f), and would lead to inventories that are considerably less complete and transparent than those that are currently reported by Annex I Parties.

While current CRF tables provide an excellent technical starting point for the development of CRTs, a number of minor and technical improvements could be implemented. These relate, for example, to how petroleum products or indirect GHGs are presented within the tables. Discussions held to date in the context of the transparency negotiations have focused only marginally on these technical issues. It is

nevertheless important that these elements are taken into account in the SBSTA's work of developing CRTs. To address these improvements, it could be useful to allow for further opportunities for input from the technical community and inventory compilers, who can provide important insights drawing from their experience with current CRF tables. Such inputs could be provided either through informal consultations or a workshop or, more formally, through the submission of written comments to the SBSTA.

3.2. How important is it to include discussions of the CRT Reporter during more general discussions relating to CRTs?

Transparency discussions on CRTs for national GHG inventories focus on the structure and design of the CRTs. However, if the CRTs build upon the current reporting system, the CRT Reporter needs to be a central element of the discussions. The CRT Reporter is key to facilitating CRT reporting and thus reducing the reporting burden for developing countries. Current experience with the CRF Reporter offers numerous insights for improvement (see (Falduto, Wartmann and Rocha, 2020^[6])) for details on potential improvements identified). If implemented, these improvements could reduce developing countries' challenges in transitioning to a new reporting system.

Timing is a key factor that needs to be addressed in the context of the negotiations. Experience shows that updating the CRF Reporter by the UNFCCC Secretariat can take considerable time and needs to be well managed and resourced. The CRF Reporter was originally designed to facilitate reporting compliant with the Revised IPCC 1996 Guidelines, and was subsequently updated (including with regards to categories and gases) to allow Annex I Parties to report in line with the IPCC 2006 Guidelines starting in 2015. A number of technical issues (e.g., with regards to incorrect aggregation of sectoral sub-totals) emerged as Parties aimed to generate CRF tables for their 2015 GHG inventory submissions. This caused several months' of delays in Annex I Parties' reporting which resulted in a number of reviews of Annex I Parties GHG inventory reports foreseen for 2015 to only take place in 2016. Should a tool similar to the CRF Reporter be used for reporting under the ETF, the time needed to develop and test the software needs to be carefully considered so that the tool is ready in time to allow reporting of the first BTR due by 31 December 2024 at the latest. Parties will need a number of months to familiarise themselves with the tool, so it would need to be available by mid-2024 at the absolute latest if it is to be used for GHG inventories reported as part of the first BTR. A further relevant consideration related to timing is that developed countries will be submitting their first annual GHG inventory reports under the Paris Agreement in April 2023 as the obligation to report GHG inventories on an annual basis continues for those Parties. This would, however, mean that the tool would need to be available in late 2022 to allow sufficient time for developed countries to familiarise themselves with it and update their existing software solutions so they can report into the CRT Reporter.

3.3. A common software or a common set of tables?

A minority of Parties are of the view that, were all relevant information was entered into a common software (i.e., a CRT Reporter), the MPG's requirement of using a set of Common Reporting Tables could be considered fulfilled, even if the tables generated from that software were not the same across all Parties. In principle, this approach is not consistent with the MPGs, which explicitly require Parties to use a set of *Common Reporting Tables* and not a common Software. Furthermore, it is not clear whether handing over only electronic information to the UNFCCC secretariat constitutes a "submission" as, assuming that XML files are handled by the UNFCCC as they are being handled in the current system, this information would not be publicly available. Different tables could result from Parties, e.g., not reporting on certain gases or certain years and the CRT Reporter only generating those parts of tables that have been filled in. This approach would nevertheless significantly reduce the transparency of reporting, as well as comparability

and consistency of reporting across different Parties. In fact, where such an approach is desired, the CRT Reporter itself would need to be the official reporting mechanism as opposed to the CRTs, as only the software contains the dataset reported. Review activities under the UNFCCC would need to be based on the complete dataset fed into tools, as assessing tables with different formats would likely take longer. Ideally, these comprehensive datasets in the software could be shared through the UNFCCC to enable usage of the GHG inventory reporting data outside of the UNFCCC Secretariat, e.g., for research activities.

3.4. What other tools could further support CRT-reporting for developing countries?

Where a GHG inventory is compiled using the IPCC Inventory Software, the software will include all data to be entered into the CRF reporter, like activity data and GHG estimations. At present, the IPCC Inventory Software does not provide the functionality to export such data in a format that can be used to populate the data fields in the CRF Reporter. An integrated approach, which would allow Parties to both compile their GHG inventories and report into the future CRT Reporter using the IPCC Inventory Software, would allow for a much more efficient compilation and reporting process. After the GHG inventory compilation, data would not need to be restructured to fit the CRT Reporter requirement, but data could be automatically generated in the format required. The IPCC plans to update the IPCC Inventory Software to generate an XML file that can be directly imported into the CRF Reporter once the CRTs have been agreed upon. Applying the needed modifications to render the IPCC Inventory Software compatible with the CRT Reporter may represent an ideal solution for developing countries with limited technical capacities. The IPCC Inventory Software could replace the need to use various software programs to prepare the GHG inventory and function as a unique software solution. Due to its limitations, at present, the IPCC Inventory Software may nevertheless not be a good solution for countries with extensive inventories and with a large LULUCF sector. Indeed, such limitations could be overcome with further updates of the software, for example, if the IPCC Inventory Software is updated to allow import from other tools explicitly designed to prepare LULUCF data.

3.5. How could the CRTs and the CRT Reporter continue facilitating international transparency?

CRTs will likely continue to represent an important source of information on national and global GHG emissions for governments and the international community. For this reason, it may be relevant to take this aspect into account when discussing their design and structure. To facilitate the use of the data they contain, the CRTs need to allow for reporting that is as standardised as possible. That is, prefer the use of standardised elements such as notation keys where possible and avoid the provision of key information in a non-standardised textual format. If qualitative data needs to be provided, it would be preferable if this is done through the use of drop-down menus that offer a list of possible textual explanations. These could include, for example, country-specific category names. Further information in a textual/narrative format can also be provided in the NID.

Currently, CRF tables are made publicly available in an MS Excel (.xlsx) format. This format is convenient and handy for readers and reviewers as it presents information in a structured way. However, as CRF data is needed for comprehensive analysis and data-processing functions, and while retaining the MS Excel format as the first prioritized format, availability of inventory data also in other formats may greatly facilitate these processes. For example, XML can be processed by a variety of software and applications.

4. Conclusions

The ETF of the Paris Agreement introduces a new reporting framework under which all Parties will be required to regularly report national GHG inventories using a common set of guidelines and a set of CRTs. The design and structure of the set of CRTs to be developed have been under discussion since 2018. While some progress has been made since then, several sticking points, mostly political, remain unresolved. Outcomes of the consultations held to date are reflected in the SBSTA informal note by the co-facilitators (UNFCCC, 2019^[13]). Overall, there is an emerging convergence around the view that the CRF tables, i.e., the tabular formats that Annex I Parties are currently mandated to use to report national GHG inventories to the UNFCCC, could serve as a starting point for the development of CRTs. Ongoing discussions on the development of CRTs can benefit from a good understanding of the current functioning of the CRF system. To this end, this paper provides background information on the functions and aims of CRF tables and current GHG inventory reporting approaches and tools.

The CRF tables that Annex I Parties currently use for their annual GHG inventory reporting under the Convention consist of a set of 49 tables that include mostly quantitative information on national GHG emissions at the category, sectoral, and summary level, including on trends. The reporting process is supported by a software tool called the “CRF Reporter” that is freely supplied by the UNFCCC Secretariat. This CRF Reporter generates the CRF tables upon Parties’ entry of relevant GHG data. The CRF Reporter is not an emission-calculation tool, and therefore emissions data needs to be calculated beforehand. Data can be inputted into the CRF Reporter in three different ways: (i) manually inputting data into the data-entry fields of the software; (ii) inputting data into offline MS Excel template tables and uploading these into the CRF Reporter and (iii) uploading a CRF-compatible XML file containing all the necessary information into the CRF Reporter. Upon entering GHG emission data and activity data at the category level into the CRF Reporter, the tool automatically populates background, sectoral, and summary tables. Once all relevant data is entered, the CRF Reporter generates CRF-tables (in .xlsx, readable by MS Excel) as well as a machine-readable XML-file. The automatisisation function that the CRF Reporter offers reduces reporting burden and the risk of human error in aggregating and replicating data. However, accurate checks are needed in lower-level tables to ensure that the estimates inputted in the Reporter are correct.

The GHG inventory process consists of two phases: GHG inventory preparation and GHG inventory reporting. Table 2 shows the two phases and key steps of these phases, as well as the relevant tools which can support each step¹⁵. The discussions around CRTs are only related to the reporting phase (phase two) of GHG inventories. As part of the reporting of GHG inventories, common reporting tables help organize emissions information and supporting information into a more transparent format. Non-Annex I Parties are already required to report national GHG inventories to the UNFCCC, reporting less comprehensive data and not submitting such data through a common reporting software. Non-Annex I Parties thus have experience with both preparing and reporting GHG inventories; however, they do not have experience in using the CRF Reporter or another software that generates comprehensive reporting tables such as the CRF tables. Using CRTs and the CRT Reporter to report national GHG inventories would not necessarily represent an increase in burden in terms of information that needs to be collected and produced, as the information included in the current CRF tables consists of information necessary to

¹⁵ The table does not list steps ensuring GHG inventory quality separately, as these form an integral part of each step presented.

estimate national GHG emissions, irrespective of the format in which they are presented. Rather, the CRTs and the CRT Reporter may represent an increase in reporting burden in terms of IT arrangements needed to ensure a smooth running of the process, unless an IT solution that facilitates GHG inventory compilation and reporting into the CRT Reporter can be made available in the future.

The domestic IT arrangements in place can influence the amount of time and the resources needed to input data into the CRT Reporter and generate the CRTs. Most Annex I countries have, over time, developed IT systems for GHG inventory compilation that facilitate reporting through the CRF Reporter. This has been a long-term process of gradual, incremental improvements, and the systems and IT arrangements developed thus far vary considerably across countries. This paper provided an overview of the IT arrangements put in place by France, Japan, the United Kingdom, and the Latin American GHG inventory network (Red Ingei). These countries' experience highlights that solutions based on a combination of common tools like MS Excel and MS Access can easily be tailored to a country's needs and require limited to no training of GHG inventory experts. Experience from Lebanon, also explored in this document, shows that IT arrangements put in place for Non-Annex-I-reporting could potentially only need minor updating to be adjusted for CRF Reporting. For all countries, enhancing and refining the systems in a step-wise manner over time could help tailor the system to a country's changing needs.

While using a combination of different software may help design IT systems that can easily be tailored to a country's needs, this approach may be challenging for Parties with limited reporting and technical capacity. To facilitate these countries' transition to a CRT system, an IT solution that foresees the use of a unique software capable of accompanying the country through multiple inventory process steps may be more convenient. In this context, and if adequately improved, the IPCC Inventory Software could represent an excellent opportunity. The IPCC Inventory Software facilitates GHG inventory compilation based on the IPCC 2006 Guidelines and is used by many developing countries. The IPCC Inventory Software is a calculation tool that facilitates reporting as it currently allows the generation of tables that are consistent with the format and structure of the tables that Non-Annex I Parties are requested to use for reporting in their National Communications and that are contained in the Annex to decision 17/CP.8. The calculation functions are, for the time being, limited to Tiers 1 and 2. The reporting tables generated by the IPCC Inventory Software are at present not compatible with the CRF Reporter. It is, however, planned to allow the exporting of GHG inventory data in a format that can be uploaded directly into the CRT Reporter in the future, once the structure of the CRTs has been agreed upon and upon the availability of resources.

At present, data in the CRF tables are used for a number of national and international purposes beyond reporting to the UNFCCC. The machine-readable data in the XML files are fed into tools provided by the UNFCCC Secretariat, which support the GHG inventory review processes under the UNFCCC. This data could also support the global stocktake in the future. A number of domestic or international research institutions regularly analyse the data in CRF tables provided on the UNFCCC website. Much effort has been put into automatising these processes as the CRF-tables are not machine-readable. As long as the information is not provided in a machine-readable manner, this process will have to be repeated every time the format is changed.

The discussions on a common reporting format for GHG inventories under the Paris Agreement currently focus on the tabular format itself, for example, how the current CRF tables would need to be amended. The transparency of the CRF tables and the effort related to filling and using them depends mainly on the CRF Reporter's functions and output formats, e.g., in which format data can be uploaded into the CRT Reporter and whether outputs generated by the CRT Reporter are machine-readable. Therefore, these functions, output formats (e.g., whether the .xlsx-file are formatted to also be machine-readable), and approach to sharing them (e.g., making the reported XLM-files publicly available just as the CRF tables are) need to be an integral part of the discussion on common tabular formats.

The time required to update and test a new CRT Reporter, as well as the time needed by Parties to familiarise themselves with the new software and integrate it into their existing software solutions, is a

critical aspect. The tool will be needed in time to be used by countries to prepare their BTR by 31 December 2024. Developed country Parties will submit their annual GHG inventories under the Paris Agreement for the first time in April 2023. Ideally, the CRT reporter would be available in time to support this reporting process. Such timing can, however, be considered challenging, as CRTs are to be agreed upon in November 2021 if COP26 takes place as planned and is not further delayed due to the Covid-19 pandemic. Developing and testing the software would then have to happen within just one year, which can be considered extremely challenging.

Table 2. Overview of the inventory process and relevant tools

Phase	Step ¹⁶	What tools and software could be used to perform this task?
One: Preparing the GHG inventory	Data collection	Spreadsheet solutions, tailored software. Data can be collected manually and stored in MS Excel spreadsheets. Data collection can also be automatized and data inputted by data providers directly into a bespoke software.
	Data standardisation	Spreadsheet solutions. If collected data is rather homogeneous, data standardization can be performed with e.g. MS Excel. If more complex operations are required, use of e.g. R may be helpful.
	Estimation of emissions	Spreadsheet solutions, database solutions, bespoke software. Depending on the complexity of the calculations to be performed, different software can be used, including MS Excel, IPCC Inventory Software, R. Database management software (e.g. MS Access, MySQL) can be used to store estimated emissions. Countries may also use bespoke software to estimate emissions.
Two: Reporting the GHG inventory to the UNFCCC	Structuring data into the required reporting format for the CRF Reporter	Database solutions (e.g., MS Access, MySQL)
	Uploading into CRF Reporter software	Database solutions, CRF Reporter templates

Source: Authors.

¹⁶ The steps presented focus on the perspective of reporting GHG inventories using common reporting formats. Some steps of the GHG inventory reporting cycle which happen after the GHG inventory reporting, like archiving and continuous improvement, are therefore not included in the table.

Annex A. The Common Reporting Formats

Table A A.1. Overview of CRF tables currently required to be reported by Annex I Parties

TABLE 1 : Sectoral Report for Energy	
Sectoral background data for energy	TABLE 1.A(a) Fuel combustion activities sectoral approach
	TABLE 1.A(b) CO ₂ from fuel combustion activities
	TABLE 1.A(c) Comparison of CO ₂ emissions from fuel combustion
	TABLE 1.A(d) Feedstock, reductants and other non-energy use of fuels
	TABLE 1.B.1 Solid fuels
	TABLE 1.B.2 Oil, natural gas and other emissions from energy production
	TABLE 1.C CO ₂ transport and storage
	TABLE 1.D International aviation and international navigation (international bunkers) and multilateral operations
TABLE 2 (I) and (II) : Sectoral Report for Industrial Processes and Product Use (IPPU)	
Sectoral background data for IPPU	TABLE 2(I).A-H Emissions of CO ₂ , CH ₄ and N ₂ O
	TABLE 2(II).B-H Sources of fluorinated substances
TABLE 3 : Sectoral Report for Agriculture	
Sectoral background data for agriculture	TABLE 3.A Enteric fermentation
	TABLE 3.B(a) CH ₄ emissions from manure management
	TABLE 3.B(b) N ₂ O Emissions from Manure Management
	TABLE 3.C Rice cultivation
	TABLE 3.D Direct and indirect N ₂ O emissions from agricultural soils
	TABLE 3.E Prescribed burning of savannahs
	TABLE 3.F Field burning of agricultural activities
	TABLE 3.G-I CO ₂ emissions from liming, urea application and other carbon containing fertilizers
TABLE 4 : Sectoral Report for Land Use, Land-use Change and Forestry (LULUCF)	
Sectoral background data for LULUCF	TABLE 4.1 Land transition matrix
	TABLE 4.A Forest Land
	TABLE 4.B Cropland
	TABLE 4.C Grassland
	TABLE 4.D Wetlands
	TABLE 4.E Settlements
	TABLE 4.F Other land
	TABLE 4.A Forest land
	TABLE 4(I) Direct nitrous oxide (N ₂ O) emissions from nitrogen (N) inputs to managed soils
	TABLE 4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils
	TABLE 4(III) Direct nitrous oxide (N ₂ O) emissions from nitrogen (N) mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils
	TABLE 4(IV) Indirect nitrous oxide (N ₂ O) emissions from managed soils
	TABLE 4(V) Biomass burning
	TABLE 4.G Harvested wood products

TABLE 5 : Sectoral report for waste	
Sectoral background data for waste	TABLE 5.A Solid waste disposal
	TABLE 5.B Biological treatment of solid waste
	TABLE 5.C Incineration and open burning of waste
	TABLE 5.D Wastewater treatment and discharge
TABLE 6 : Cross-sectoral report: Indirect emissions of N₂O and CO₂	
TABLE 7 : Summary overview for key categories	
TABLE 8 : Recalculation	
TABLE 9 : Completeness – Information on notation keys	
TABLE 10 : Emission trends (one sheet per greenhouse gas and one sheet for aggregate GHG emissions)	
SUMMARY 1.A : Summary report for national greenhouse gas inventories (in kt)	
SUMMARY 2 : Summary report for national GHG inventories in CO₂ equivalent	
SUMMARY 3 : Summary report for methods and emissions factors used	

Source: Falduto, Wartmann and Rocha (2020).

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