QUALITY MANUAL FOR THE DANISH GREENHOUSE GAS INVENTORY

Version 3

Scientific Report from DCE – Danish Centre for Environment and Energy No. 406 2020

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Abstract: This report outlines the quality work undertaken by the emission inventory group at the Department of Environmental Science, Aarhus University in connection with the preparation and reporting of the Danish greenhouse gas inventory. This report updates and expands on the first versions of the quality manual published in 2005 and 2013. The report fulfils the mandatory requirements for a quality assurance/quality control (QA/QC) plan as lined out in the UNFCCC reporting guidelines and the specifications related to reporting under the Kyoto Protocol. The report describes all elements of the internal QC procedures as well as the QA and verification activities carried out in connection with the Danish greenhouse gas inventory.

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Contents

List of abbreviations

CCP	Critical Control Point
COP	Conference of the Parties
CRF	Common Reporting Format
DCE	Danish Centre for Environment and Energy
IEF	Implied Emission Factor
IPCC	Intergovernmental Panel on Climate Change
NIR	National Inventory Report
PM	Point of Measurement
QA	Quality Assurance
QC	Quality Control
QP	Quality Plan
SNAP	Selected Nomenclature for Air Pollution
UNFCCC	United Nations Framework Convention on Climate Change

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Preface

The Danish Centre for Environment and Energy (DCE), Aarhus University is contracted by the Ministry of Environment and Food and the Ministry of Climate, Energy and Utilities to compile and report emission inventories for Denmark. The Department of Environmental Science, Aarhus University is responsible for the compilation and reporting of the Danish national greenhouse gas emission inventory to the European Union, the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol.

This report outlines the quality work undertaken by the emission inventory group at the Department of Environmental Science, Aarhus University in connection with the preparation and reporting of the Danish greenhouse gas inventory. This report updates and expands on the first and second versions of the quality manual published in 2005 and 2013.

The report fulfils the mandatory requirements for a quality assurance / quality control (QA / QC) plan as lined out in the UNFCCC reporting guidelines and the specifications related to reporting under the Kyoto Protocol.

The report has been lead authored by Ole-Kenneth Nielsen and has been commented, complemented and quality controlled by the other members of the emission inventory group listed as authors.

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The authors of this third version of the report wish to thank Peter B. Sørensen, who was the architect of the QA / QC system for the Danish greenhouse gas emission inventory and was the lead author of the first version of the QA / QC manual. In addition, the authors would like to thank the former members of the Danish emission inventory team for their contributions.

Furthermore, the authors would like to thank the Danish and international experts that have contributed to peer-reviews of sectors of the inventory during the years. The valuable input received during the reviews has greatly increased the quality of the Danish greenhouse gas inventory.

Summary

This report is a manual for the Quality Control and Quality Assurance of greenhouse gas emission inventories performed by the Department of Environmental Science. This third version updates the second version published in 2013. While the basic structure of the QA/QC remains the same some changes have been made following the experiences by the Danish inventory team since 2013, furthermore the lessons learned through the different QA processes have been used in expanding and improving the QC work undertaken by the Danish inventory team. The manual will be continuously reviewed and updated as necessary. The manual is elaborated as required by the UNFCCC reporting guidelines, the decision establishing a National System under the Kyoto Protocol. The QA/QC manual adheres to the technical guidance provided by the IPCC. Some extensions have been made to complete the manual. The ISO 9000 standards are also used as important input for the structure of the manual. The work with quality is sub divided into the following elements:

- Quality Management, that co-ordinates activities with regard to the quality system.
- Quality Planning, where quality objectives are defined including specification of necessary operational processes and resources to fulfil the quality objectives.
- Quality Control, that secures fulfilling of quality requirements.
- Quality Assurance that provides confidence for fulfilment of quality requirements.
- Quality Improvement that increases the ability to fulfil quality requirements.

In the ISO 9000, the term quality relates to the fulfilment of requirements, where the requirements are generated from need or expectations as stated by either organizations, customers or interested parties. The organizations can be seen as the international community. The requirements from the international community are assumed to be reflected in the UNFCCC reporting guidelines and the IPCC Guidelines.

A solid and clear definition of when the quality is sufficient is an essential platform for the Quality Management. However, such a definition is missing in the UNFCCC reporting guidelines. The standard of the inventory result is defined as being composed of the accuracy and regulatory usefulness. The goal is to maximise the standard of the inventory and the following statement defines the quality objective:

The quality objective is only inadequately fulfilled if it is possible to make an inventory of higher standard without exceeding the frame of resources.

This statement does not secure that the inventory provides results of a sufficient standard for the end-user. If the standard is judged to be unsatisfactory by the end-user on one hand while the Quality Assurance shows the quality to be sufficient on the other hand, then a demand for additional resources for inventory work exists. If this is the case, the resource responsible authorities are to be consulted.

The Quality Planning is based on the data flow in the inventory. The flow of data has to take place in a transparent way by making the transformation of data detectable. It is important that it is easy to find the original background data for any calculation and easy to trace the sequence of calculations from the raw data to the final emission result.

The objectives for the Quality Management, as formulated by *IPCC Guidelines* and the *UNFCCC* reporting guidelines, are to improve elements of transparency, consistency, comparability, completeness and accuracy. Two other factors are included in this manual as they are deemed important to the quality of the inventory: (1) Robustness of the inventory in relation to change in conditions like staff and external data availability. (2) Correctness of the data handling by elimination of miscalculation.

The means for the Quality Planning have to be detailed measurable checkpoints imbedded throughout all activities in the inventory and they are denoted Point of Measurements (*PMs*). A consolidated version of a *PM* listing is reported in this manual compared to the first version of the manual. Several additional PMs have been added based on the experiences gained. Furthermore, some PMs have been reworded to more closely match the identified need or deleted.

Sammenfatning

Denne rapport er en manual til kvalitetssikring og kvalitetskontrol af den årlige danske rapportering af drivhusgasemissioner. Rapporten er udarbejdet af Aarhus Universitet, Institut for Miljøvidenskab. Denne 3. udgave er en opdatering af version 2, som udkom i 2013. Selvom basisstrukturen for kvalitetssikringen og –kontrollen forbliver den samme, er der foretaget nogle ændringer som følge af det danske review-teams erfaringer siden 2013. Derudover har de erfaringer, der er opnået gennem de forskellige QA-processer, været med til at udvide og forbedre QC-arbejdet. Manualen vil også fremover løbende blive reviewet og opdateret. Manualen er udformet i overensstemmelse med UNFCCC's rapporteringsguidelines, som foreskriver etablering af et nationalt system, der refererer til Kyotoprotokollen. Ydermere følger QA/QC-manualen den tekniske vejledning udarbejdet af IPCC, og der er lavet tilføjelser for at fuldende manualen. ISO 9000-standarderne benyttes også som vigtigt input til opbygningen af manualen. Kvalitetsdelen er underopdelt på følgende vis:

- Kvalitetsstyring (Quality Management) der koordinerer aktiviteter i forhold til kvalitet.
- Kvalitetsplanlægning (Quality Planning) hvor kvalitetsmål er defineret, inklusiv specifikation af nødvendige tiltag og nødvendige ressourcer til opfyldelse af målsætningen.
- Kvalitetskontrol (Quality Control) der sikrer, at planlagte tiltag udføres i praksis.
- Kvalitetssikring (Quality Assurance) der kan dokumentere at den ønskede kvalitet faktisk er til stede.
- Kvalitetsforbedring (Quality Improvement) der øger muligheden for forbedret kvalitet.

I ISO 9000 er termen 'kvalitet' relateret til opfyldelse af de behov og krav, der er fremsat som forventninger fra enten virksomheder, kunder eller interessenter.

Virksomhederne kan ses som det internationale samfund, der ønsker en udredning af emissioner. Kravene fra det internationale samfund er antaget reflekteret i såvel FN's UNFCCC rapporteringsguidelines som i IPCC's guidelines.

En tydelig og klar definition af hvornår kvalitet er tilstrækkelig, er et vigtigt udgangspunkt for kvalitetsstyring. En sådan definition mangler dog i de to UNFCCC og IPCC rapporteringsguidelines.

Standarden for emissionsopgørelsen er defineret til at bestå af nøjagtighed og brugbarhed. Formålet er at forbedre emissionsopgørelsens standard. Følgende definition beskriver kvalitetsmålsætningen:

Kvalitetsmålsætningen er kun utilstrækkeligt opfyldt, hvis det er muligt at lave en opgørelse af højere standard uden brug af ekstra ressourcer.

Dette udsagn sikrer ikke, at opgørelsen tilvejebringer en høj nok kvalitet af resultatet til slutbrugerne. Hvis en standard på den ene side vurderes til at være ufyldestgørende for slutbrugerne, mens kvalitetssikringen på den anden

side viser, at kvaliteten er tilstrækkelig, så er der behov for yderligere ressourcer til arbejdet med opgørelserne. Er dette tilfældet, skal de bevilgende instanser kontaktes.

Kvalitetsplanlægningen er baseret på opgørelsens bagvedliggende dataflow. Dataflowet skal foregå på en gennemskuelig måde ved at gøre al beregnet data synlig. Det er vigtigt, at det er let at finde frem til den originale baggrunddata ved evt. genkalkulation og let at spore rækkefølgen af beregninger fra rådata til den endelige emissionsopgørelse.

Kvalitetsstyringen har, som formuleret i IPCC- og UNFCCC-guidelines, til formål at forbedre forskellige elementer så som transparens, konsistens, sammenlignelighed, fuldkommenhed og præcision. To andre faktorer er inkluderet i denne manual, da de skønnes vigtige for kvaliteten af emissionsopgørelsen: (1) Robustheden af emissionsopgørelsen i forhold til ændringer i vilkårene som f.eks. personale og datatilgængelighed. (2) Optimere korrektheden af databearbejdning ved at udelukke muligheden for fejlberegninger.

Points of Measurements (PM'er) er et metode der optimerer kvalitetsplanlægningen. PM'er er detaljerede målbare kontrolpunkter, som dækker alle aktiviteter i emissionsopgørelsen. En styrket version af PM'er er inkluderet i denne manual i forhold til den første version af manualen. Således er adskillige PM'er tilføjet, baseret på de opnåede erfaringer. Derudover er nogle PM'er omformuleret for bedre at matche de identificeret behov, mens andre PM'er er fjernet.

1 Introduction

This report is a quality manual for the Quality Control (QC) and Quality Assurance (QA) for the Danish greenhouse gas emission inventory performed by the Department of Environmental Science, Aarhus University. The quality procedure is continuously improved as part of the ongoing process of improving the emission inventory. The quality manual is thus periodically updated when the need arises. The first version of this manual was published in 2005 (Sørensen et al., 2005) and this was updated in 2013 (Nielsen et al., 2013). This report is the third version updating the second version published in 2013. Compared to the first version, several changes have been made, including adding new points of measurements, deletion of points of measurements, redefinition of points of measurements and an extended description of QA procedures.

The changes made reflects the experiences gained by the emission inventory team during the past seven years as well as input received during the QA process of the inventory both in connection with UNFCCC reviews but also from the EU internal review and the national QA activities undertaken.

The quality manual is in accordance with the reporting guidelines provided by the UNFCCC (UNFCCC, 2014) and the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006), hereinafter the IPCC Guidelines, with some extensions. The ISO 9000 standards are also used as important input for the structure of the manual. The QA / QC activities - as described in this manual - governs work that only use external data and the persons who are directly involved in this work are denoted *inventory staff*. This manual sets up guidelines for the work by *inventory staff*. The *inventory staff* is located in the Department of Environmental Science, Aarhus University, Denmark.

First, the concept of quality is defined using conventional terminology and the interaction between different elements is briefly outlined. The quality goal is defined and from that, a listing of basic factors to take into account is made. This forms the platform for concrete tasks to be done in order to fulfil the quality goal. Finally, a reporting structure is outlined in which every task is addressed.

In this version of the report, several changes have been made compared to the first version. Changes have been made to specific Point of Measurements (PMs) based on experiences both from the internal evaluation and from input from external reviews.

Other changes include a more clear description of the connection between the Danish quality manual and the relevant UNFCCC and IPCC Guidelines and a description of the QA and verification activities undertaken as part of the operation of the Danish greenhouse gas emission inventory.

2 Concepts of quality work

Quality is in ISO 9000 defined as the degree to which a set of inherent characteristics fulfils requirements. Requirements are the need or expectation that is stated, generally implied of obligatory. The quality planning is based on the following definitions as lined out by both ISO 9000 standards and it covers the activities lined out by the UNFCCC and the IPCC Good Practice Guidance:

- Quality management (*QM*) co-ordinate activities with regard to the quality system
- Quality Planning (*QP*) defines quality objectives including specification of necessary operational processes and resources to fulfil the quality objectives
- Quality Control (*QC*) fulfils quality requirements
- Quality Assurance (*QA*) provides confidence that quality requirements will be fulfilled
- Quality Improvement (*QI*) increases the ability to fulfil quality requirements

The activities are considered inter-related in this work as shown in Figure 1.

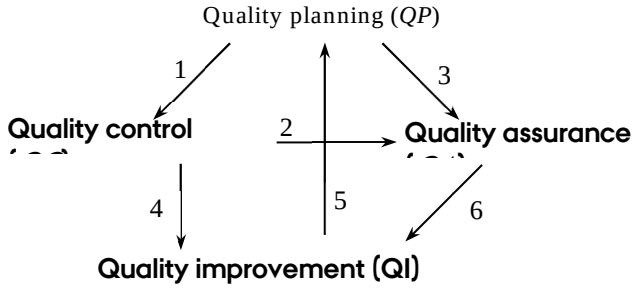


Figure 1 The Inter-relation between the activities with regard to quality. The arrows are explained in the following:
1: The *QP* sets up the objectives and from these measurable properties valid for the *QC*.
2: The *QC* investigates the measurable properties that are communicated to the QA for assessment in order to ensure sufficient quality.
3. The *QP* identifies and defines measurable indicators for the fulfilment of the quality objectives. They form the basis for the *QA* and have to be supported by the input coming from the *QC*.
4: The result from *QC* will highlight the degree of fulfilment for every quality objective. It will thus be a good basis for suggestions of improvements of the inventory to meet the quality objective.
5: Suggested improvements in the quality may induce changes in the quality objectives and their measurability.
6: The evaluation done by external authorities is important input when improvements in quality are considered.

3 Definition of sufficient quality

A solid definition of when the quality is sufficient is essential. Without this, the fulfilment of the objectives will never be clear and the process of quality control and assurance can easily turn out to be a fuzzy and unpleasant experience for the people involved. Contrary, in case of a solid definition and thus a clear goal, it will be possible to make a valid statement of "good quality" and thus form constructive conditions and motivate the inventory work positively. A clear definition of sufficient quality has not been given in the UNFCCC reporting guidelines (UNFCCC, 2014). In the IPCC Guidelines Volume 1, Chapter 6.2 (IPCC, 2006), however, it is mentioned that:

"Quality control requirements, improved accuracy and reduced uncertainty need to be balanced against requirements for timeliness and cost effectiveness".

However, the statement of balancing requirements and costs is not a solid basis for QC as long as this balancing is not well defined.

In the ISO 9000, the quality is based on the fulfilment of requirements, where the requirements are generated from needs or expectations as stated by either organisations, customers or interested parties. The organisations can be seen as the international community that requires the results from the inventory. The requirements from the international community are assumed to be reflected in the UNFCCC reporting guidelines (UNFCCC, 2014) and the IPCC Guidelines (IPCC, 2006).

The standard of the inventory result is defined as being composed of the accuracy and regulatory usefulness. The goal is to maximise the standard of the inventory and the following statement defines the quality objective:

The quality objective is only inadequately fulfilled if it is possible to make an inventory of higher standard without exceeding the frame of resources.

This statement does not secure that the inventory provides results of a sufficient standard for the end-user. The problem is that the end-user does not explicitly communicate standards that have to be fulfilled. This makes it impossible to develop a quality system that with certainty can ensure the results of the standard required by the end-user. However, the QA/QC results are useful for assessing the standard of the inventory. If the standard is judged unsatisfactory by the end-user while the *QM* shows the quality to be sufficient then a demand for additional resources for the inventory work exists. In this case, the resource responsible authorities have to be consulted.

4 Process oriented QC

The strategy is based on a process-oriented principle (ISO 9000 series) and the first step is thus to set up a system for the process of the inventory work. The product specification for the inventory is a dataset of emission figures and the process is thus identical with the data flow in the preparation of the inventory.

The data flow needs to support the QC in order to facilitate a cost effective procedure. The flow of data has to take place in a transparent way by making the transformation of data detectable. It needs to be easy to find the original data background for any calculation and to trace the sequence of calculations from the raw data to the final emission result. Computer programming for automated calculations and checking will enhance the accuracy and minimise the number of miscalculations and flaw in input value settings. Especially manual typing of numbers needs to be minimised. This assumes, however, that the quality of the programming has been verified to ensure the correctness of the automated calculations. Automated value control is also one of the important means to secure accuracy. Realistic uncertainty estimates are necessary for securing accuracy, but they can be difficult to make, due to the uncertainty of the uncertainty estimates itself. It is therefore important to include the uncertainty calculation procedures into the data structure as much as possible. The QC needs to be supported to as wide an extent as possible by the data structures, otherwise the procedure can easily become troublesome and subject for frustration.

Both data processing and data storage forms the data structure. The data processing is done using mathematical operations or models. It may be complicated models for human activity or simple summations of lower aggregated data. The data storage includes databases and file systems of data that are either calculated using the data processing at the lower level or using input to new processing steps or even both output and input in the data structure. The measure for quality is basically different for processing and storage so this needs to be kept separate in a quality manual.

The data storage takes place for the following types of data:

***External Data*:** a single numerical value of a parameter coming from an external source. This is thus basic input, as the *inventory staff* does not measure any new data. These data govern the calculation of *Activity-Release Data.*

***Activity-Release Data*:** Data for input to the final emission calculation in terms of data for release source strength and activity. The data is directly applicable for use in the standardised forms for calculation. These data are calculated using external data or represent a direct use of *External Data* when they are directly applicable for *Emission Calculations.*

***Emission Data*:** Estimated emissions based on the *Activity Release* Data.

***Emission Reporting*:** Reporting of emission data in requested formats and aggregation level.

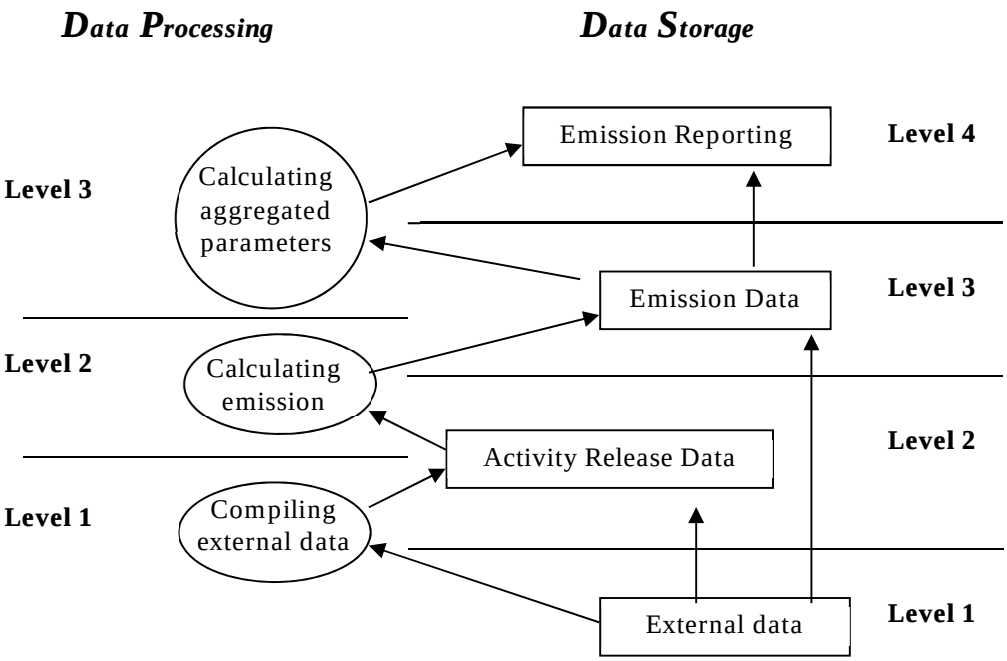


Figure 2 The general data structure for the emission inventory.

4.1 Levels for implementing QC in the work

The compilation of the greenhouse gas emission inventory is a process consisting of a long chain of different data processing and data storage steps as illustrated by Figure 2. QC should take place at each level as well as between levels to ensure correct transfer

The key levels are defined in the data structure as:

Data storage Level 1, External data

Collection of external data sources from different sectors and statistical surveys typically reported on an annual basis. The data consist of raw data, having identical format as the data received and gathered from external sources. Level 1 data acts as a base set, on which all subsequent calculations are based. If alterations in calculation procedures are made, they are based on the same dataset. When new data are introduced, they can be implemented in accordance with the QA / QC structure of the inventory.

Data storage Level 2, Data directly usable for the inventory

This level represents data that have been prepared and compiled in a form that is directly applicable for calculation of emissions. The compiled data are structured in a database for internal use as a link between more or less raw data and data that are ready for reporting. The data are compiled in a way that elucidates the different approaches in emission assessment: (1) Directly based on measured emissions especially for larger point sources. (2) Based on activities and emission factors, where the value setting of these factors are stored at this level.

Data storage Level 3, Emission data

The emission calculations are reported by the most detailed figures and divided in sectors. The unit at this level is typically mass per year for the country. For sources included in the SNAP system the SNAP level 3 is relevant. Internal reporting is performed at this level to feed the external communication of results.

Data storage Level 4, Final reports for all subcategories

The complete emission inventory is reported to UNFCCC at this level by summing up the results from every subcategory.

Data processing Level 1, Compilation of external data

Preparation of input data for the emission inventory based on the external data sources. Some external data may be used directly as input to the data processing at level 2, while others need to be interpreted using more or less complicated models, which takes place at this level. The interpretation of activity data is to be seen in connection to availability of emission factors. These models are compiled and processed as an integrated part of the inventory work.

Data processing Level 2, Calculation of inventory figures

The emission for every subcategory is calculated, including the uncertainty for all sectors and activities. The summation of all contributions from subcategories makes up the inventory.

Data processing Level 3, Calculation of aggregated parameters

Some aggregated parameters need to be reported as part of the final reporting. This will not be complicated calculations but important figures, e.g. implied emission factors at a higher aggregated level to be compared in time series and with other countries.

5 Critical Control Points (CCP)

A Critical Control Point (CCP), in this manual, is an element or an action, which needs to be taken into account in order to fulfil the quality objective. The list of CCPs will form the condition for assessing the performance in relation to the quality objective.

The objectives for the *QM* as formulated by *IPCC Guidelines* are to improve elements of transparency, consistency, comparability, completeness and accuracy. The objectives given by these guidelines are, in this manual, defined to be a list of CCP for fulfilling the real objective as defined in Chapter 3 above. The following explanation is given by UNFCCC reporting guidelines (UNFCCC, 2014) for each CCP:

Transparency means that the data sources, assumptions and methodologies used for an inventory should be clearly explained, in order to facilitate the replication and assessment of the inventory by users of the reported information. The transparency of inventories is fundamental to the success of the process for the communication and consideration of the information. The use of the common reporting format (CRF) tables and the preparation of a structured national inventory report (NIR) contribute to the transparency of the information and facilitate national and international reviews.

Consistency means that an annual GHG inventory should be internally consistent for all reported years in all its elements across sectors, categories and gases. An inventory is consistent if the same methodologies are used for the base and all subsequent years and if consistent datasets are used to estimate emissions or removals from sources or sinks. Under certain circumstances, an inventory using different methodologies for different years can be considered to be consistent, if it has been recalculated in a transparent manner, in accordance with the IPCC Guidelines.

Comparability means that estimates of emissions and removals reported by Annex I Parties in their inventories should be comparable among Annex I Parties. For that purpose, Annex I Parties should use the methodologies and formats agreed by the Conference of the Parties (COP) for making estimations and reporting their inventories. The allocation of different source / sink categories should follow the CRF tables provided in annex II to decision 24 / CP.19 at the level of the summary and sectoral tables.

Completeness means that an annual GHG inventory covers at least all sources and sinks, as well as all gases, for which methodologies are provided in the IPCC Guidelines or for which supplementary methodologies have been agreed by the COP. Completeness also means the full geographical coverage of the sources and sinks of an Annex I Party.

Accuracy means that emission and removal estimates should be accurate in the sense that they are systematically neither over nor under true emissions or removals, as far as can be judged, and that uncertainties are reduced as far as practicable. Appropriate methodologies should be used, in accordance with the IPCC Guidelines, to promote accuracy in inventories.

The five CCPs listed above are defined in the UNFCCC reporting guidelines (UNFCCC, 2014). However, in this manual they are not considered to be a complete set in order to fully secure the quality objectives in Chapter 3. The robustness against unexpected disturbance of the inventory work has to be high in order to secure high quality, which is not covered by the CCPs above.

Robustness implies arrangement of inventory work as regards e.g. inventory experts and data sources in order to minimise the consequences of any unexpected disturbance due to external and internal conditions. A change in an external condition could be interruption of access to an external data source and an internal change could be a sudden reduction in qualified staff, where a skilled person suddenly leaves the inventory work.

The correctness is not stated in the guidelines explicitly, as it may be considered part of the accuracy. However, the definition of accuracy in the guidelines is solely pointing at the task of minimising uncertainty and factors such as miscalculations are not covered by an uncertainty analysis. Thus, the term correctness is defined as an independent CCP. This is done because the correctness of the inventory is a condition for all other objectives to be effective. A large part of the general QC procedures given by the IPCC Guidelines (IPCC, 2006) is actually checks for miscalculations and thus a support of an objective of correctness.

Correctness has to be secured in order to avoid uncontrollable occurrence of uncertainty directly due to errors in the calculations. Correct data transmission from one level of the inventory to the next level is an important part of the correctness.

The different CCPs are not independent and represent different degrees of generality, e.g. deviation from *comparability* may be accepted if a high degree of *transparency* is applied. Furthermore, there may even be a conflict between the different CCPs, e.g. new knowledge may suggest improvements in calculation methods for better *completeness,* but the same improvements may partly violate the *consistency* and *comparability* with regard to former year's inventories and the reporting from other Parties. It is therefore a multi-criteria problem of optimisation to apply the set of CCPs in the activity for good quality.

6 Points of Measurement (PMs)

The CCPs have to be based on clear measurable factors. Otherwise, the QP will end up being a loose declaration of intent. Thus in Table 1 below a series of Point for Measuring (PM) is identified as building blocks for a solid QM. Table 6.1 in the IPCC Guidelines is a listing of such PMs. However, the IPCC listing is not all encompassing and a more complete listing may be needed in order to secure support for all the CCPs. Therefore, additional PMs have been identified and added to the list in Table 1.

The PMs will be routinely checked in the QC reporting and when external reviews take place, the reviewers will be asked to assess the fulfilment of the PMs.

The listing in Table 1 is the current version. The list of PMs is continuously updated so that it can take into account the findings of the different QA procedures explained in Chapter 8.

Table 1 A list of the PMs including a short description.

Level	CCP	Id	Description	
Data Storage level 1	1. Accuracy	DS.1.1.1	General level of uncertainty for every dataset including the reasoning for the specific values.	Sectoral
	2. Comparability	DS1.2.1	Comparability of the emission factors/calculation parameters with data from international guidelines, and evaluation of major discrepancies.	Sectoral
	3.Completeness	DS.1.3.1	Ensuring that the best possible national data for all sources are included, by setting down the reasoning behind the selection of datasets.	Sectoral
	4.Consistency	DS.1.4.1	The original external data has to be archived with proper reference.	Sectoral
	6.Robustness	DS.1.6.1	Explicit agreements between the external institution holding the data and NERI about the conditions of delivery.	Sectoral
		DS.1.6.2	At least two employees must have a detailed insight into the gathering of every external dataset.	General
	7.Transparency	DS.1.7.1	Listing of all archived datasets and external contacts.	Sectoral
		DS.1.7.2	The archived datasets shall be easily accessible for any person within the emission inventory team.	General
Data Processing level 1	1. Accuracy	DP.1.1.1	Uncertainty assessment for every data source not part of DS.1.1.1 as input to Data Storage level 2 in relation to type and scale of variability.	Sectoral
	2.Comparability	DP.1.2.1	The methodologies have to follow the international guidelines suggested by UNFCCC and IPCC.	Sectoral
	3.Completeness	DP.1.3.1	Identification of data gaps with regard to data sources that could improve quantitative knowledge.	Sectoral
	4.Consistency	DP.1.4.1	Documentation and reasoning of methodological changes during the time series and the qualitative assessment of the impact on time series consistency.	Sectoral
		DP.1.4.2	Identification of parameters (e.g. activity data, constants) that are common to multiple source categories and confirmation that there is consistency for these parameters in the emission calculations.	General
	5.Correctness	DP.1.5.2	Verification of calculation results using time series.	Sectoral
		DP.1.5.3	Verification of calculation results using other measures.	Sectoral

Level	CCP	Id	Description	
Continued				
	6.Robustness	DP.1.6.1	Any calculation must be anchored to two responsible persons who can replace each other in the technical issue of performing the calculations.	General
	7.Transparency	DP.1.7.1	The calculation principle, the equations used and the assumptions made must be described.	Sectoral
		DP.1.7.2	Clear reference to dataset at Data Storage level 1.	Sectoral
		DP.1.7.3	A manual log to collect information about recalculations.	Sectoral
Data Storage level 2	5.Correctness	DS.2.5.1	Check if a correct data import to level 2 has been made.	Sectoral
	6.Robustness	DS.2.6.1	All persons in the inventory team must be able to handle all data at level 2.	General
	7.Transparency	DS.2.7.1	The time trend for every single parameter must be available and any major dips/jumps in the time series are investigated and documented.	General
Data Processing level 2	1. Accuracy	DP.2.1.1	Documentation of the methodological approach for the uncertainty analysis.	General
	2.Comparability	DP.2.2.1	The inventory calculation shall follow the international guidelines suggested by UNFCCC and IPCC.	General
	6.Robustness	DP.2.6.1	Any calculation at level 2 must be anchored to two responsible persons who can replace each other in the technical issue of performing the calculations.	General
	7.Transparency	DP.2.7.1	Reporting of the calculation principle and equations used	General
		DP.2.7.2	The reasoning for the choice of methodology for uncertainty analysis needs to be written explicitly.	General
Data Storage level 3	1. Accuracy	DS.3.1.1	Quantification of uncertainty.	General
	5.Correctness	DS.3.5.1	Comparison with inventories of the previous years on the level of the categories of the CRF as well as on SNAP source categories. Any major change is checked, verified, etc.	General
		DS.3.5.2	Total emissions, when aggregated to CRF source categories, are compared with totals based on SNAP source categories (control of data transfer).	General
		DS.3.5.3	Checking of time series of the CRF and SNAP source categories as they are found in the Corinair databases. Considerable trends and changes are checked and explained.	General
	7. Transparency	DS.3.7.1	The databases and other software used shall be clearly documented. The documentation should include a description that the appropriate data processing steps are correctly represented in the database; that data relationships are correctly represented in the database and that data fields are properly labelled and have the correct design specifications.	General
		DS.3.7.2	The documentation referred to under DS.3.7.1 should be archived at the same network folder as the program is located in.	General
Data Processing level 3	6. Robustness	DP.3.6.1	The process of generating the official submissions must be anchored by at least two responsible persons who can replace each other in the technical issue of generating CRF tables including of the aggregation of submissions for Denmark and Greenland.	General
	7. Transparency	DP.3.7.1	The databases and other software used shall be clearly documented. The documentation should include a description that the appropriate data processing steps are correctly represented in	General

Level	CCP	Id	Description	
			the database; that data relationships are correctly represented in the database and that data fields are properly labelled and have the correct design specifications.	
		DP.3.7.2	The documentation referred to under DS.3.7.1 should be archived at the same network folder as the program is located in.	General
Data Storage level 4	2.Comparability	DS.4.2.1	National and international verification for the methodological approach, activity data and implied emission factors.	General
	3.Completeness	DS.4.3.1	National and international verification including explanation of the discrepancies.	General
		DS.4.3.2	Check that the no sources where a methodology exists in the IPCC Guidelines are reported as NE.	General
	4.Consistency	DS.4.4.1	The inventory reporting shall follow the international guidelines suggested by UNFCCC and IPCC.	General
		DS.4.4.2	Check time series consistency of the reporting by Greenland and the Faroe Islands prior to aggregating the final submissions.	General
		DS.4.4.3	The IEFs from the CRF are checked both regarding level and trend. The level is compared to relevant emission factors to ensure correctness. Large dips/jumps in the time series are explained.	Sectoral
	5.Correctness	DS.4.5.1	Check that the aggregated submissions for Denmark under the Kyoto Protocol and the UNFCCC match the sum of the individual submissions.	General
	5. Correctness	DS.4.5.2	Check that additional information and information related to land-use changes has been correctly aggregated compared to the individual submissions of Denmark and Greenland.	Sectoral
	6. Robustness	DS.4.6.1	The reporting to the UNFCCC must be anchored to two responsible persons who can replace each other in the technical issue of reporting to and communicating with the UNFCCC secretariat.	General
	7.Transparency	DS.4.7.1	Perform QA on the documentation report provided by the Government of Greenland.	General

The documentation of the PMs is done annually and reported in the National Inventory Report (NIR). The current version (2018) is Nielsen et al. (2018) and the latest reported version is always available from the UNFCCC website: http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/10116.php

The PMs that are specific to the sectors are reported as part of the sectoral chapters in the NIR (Chapter 3-8 and 11), while the documentation of the general PMs are included in chapter 1 of the NIR.

7 Structure and responsibilities of work and reporting

The final inventory report sums up the emission from a series of sub-categories of human activity, such as large point sources, agriculture, etc. Each subcategory needs to have an individual reporting in order to include all necessary details adding up into complete inventory reports. The structure of reporting is shown in Figure 1 and will be explained in the following paragraphs.

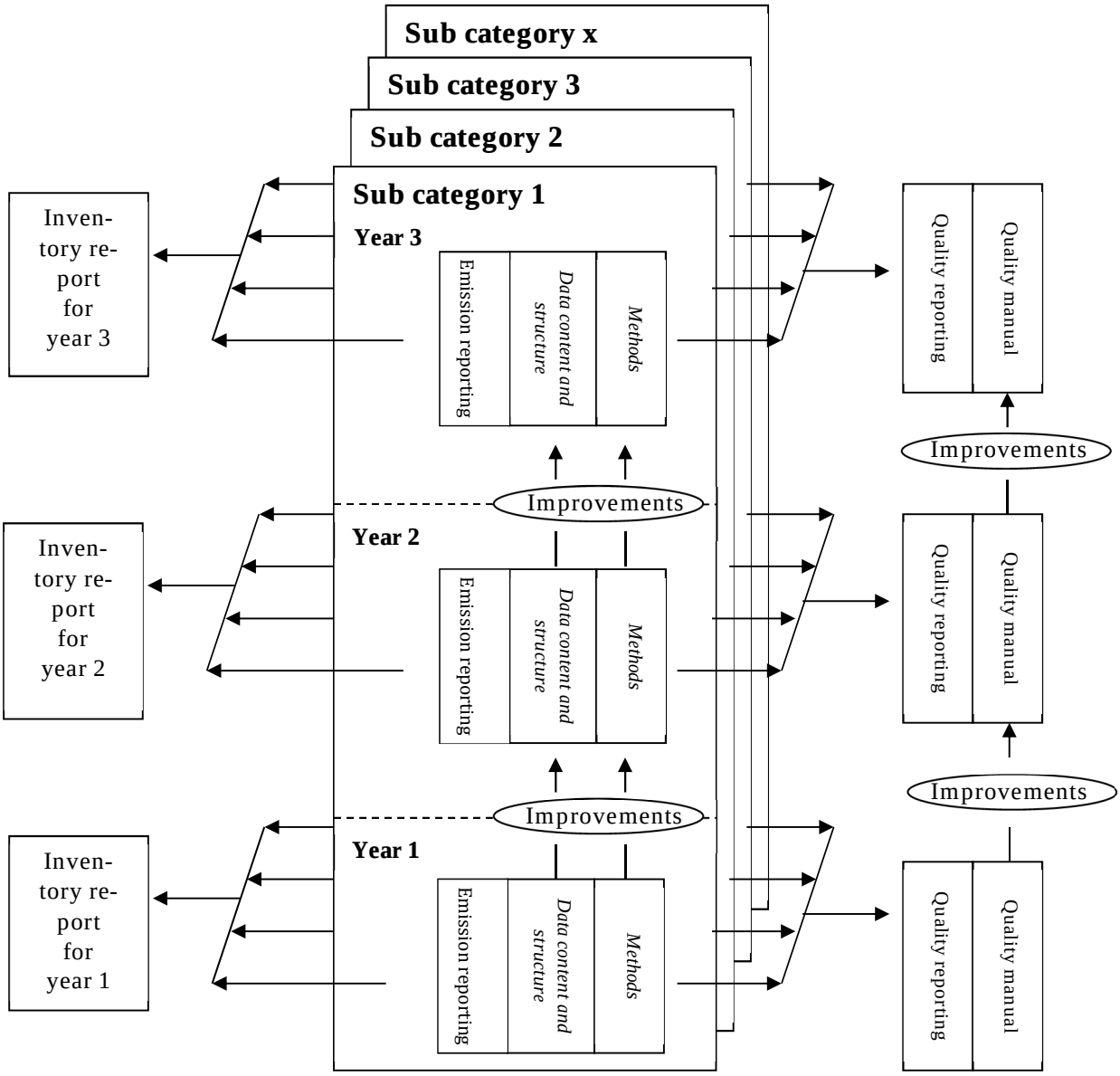


Figure 3 The general structure of reporting.

Four types of reporting activities are undertaken: (1) Annual reporting of the emission inventory (NIR), (2) Data content and Structure (DCS), (3) Methodological Description (MD), (4) Quality Reporting (QR) and (5) Quality Manual (QM). The reporting of NIR and QR present specific datasets and must thus be done every year, while reporting of DCS, MD and QM are process oriented

and thus linked to changes in methods and procedures, which are not necessarily changed from one year to another.

The DCS, MD and QR are done as part of the annual reporting of the emission inventory, i.e. in the NIR. The DCS reporting and QR is included both in the general part of the NIR and in the sectoral chapters. The MD reporting is included in the sectoral chapters of the NIR. The QM has been chosen to be published as a separate report in order to optimise transparency.

The responsibility for the sector specific QC activities is with the sectoral experts. All sectors have one of two experts that are responsible for the sectoral QC. The general QC checks and all the checks that are done at an aggregated level are the responsibility of the team leader. The team leader works closely with the person in the team responsible for data management to ensure the highest possible degree of automatism in the QC checks. The sectoral experts for the different source categories are shown in Table 2.

Table 2 List of inventory experts responsible for sectoral QC.

	Responsible experts
Energy – stationary combustion	Malene Nielsen
Energy – mobile combustion	Morten Winther
Energy – fugitive emissions	Marlene Plejdrup
Industrial processes and product use	Katja Hjelgaard
Agriculture	Mette H. Mikkelsen
	Rikke Albrektsen
LULUCF (Excl. forestry)	Steen Gyldenkærne
Waste	Marianne Thomsen
	Rikke Albrektsen

The overall responsibility for the QA / QC system for the Danish emission inventory rests with the team leader. The team leader is assisted by the data management expert. The team leader also manages the contact and dialogue with the external organisations that are directly contributing to the greenhouse gas inventory. The different organisations and the team leader and data management expert are defined in Table 3.

Table 3 Overall responsibility and external organisations directly involved in the inventory.

Role	Responsible
Overall responsibility	Ole-Kenneth Nielsen
Data management expert	Henrik G. Bruun
F-gas inventory	Tomas Sander Poulsen, Provice
Forestry inventory	Vivian Kvist Johansen, Copenhagen University
Greenlandic inventory	Tuperna Maliina Olsen, Ministry of Industry and Energy in Greenland
Faroe Islands inventory	Maria Gunnleivsdóttir Hansen, Faroe Islands Environmental Authority

DCE is responsible for the QC of the final reporting. DCE is elaborating the emission inventory for mainland Denmark for all sectors with the exception of f-gases and forestry. These two sectors are done by Provice and Copenhagen University respectively.

For the reporting under the UNFCCC and the Kyoto Protocol there are different territorial definitions. For the reporting to the UNFCCC the whole Kingdom of Denmark is included, i.e. Denmark, Greenland and the Faroe Islands. For the reporting to the Kyoto Protocol the reporting consists of Denmark and Greenland.

DCE receives data and documentation input from all the external contributors. DCE is responsible for the QC of the data received and the data enters the QC system as described in this manual on data storage level three. All the external organisations contributing are also carrying out QC according to their own internal procedures. These QC checks are documented in the relevant parts of the NIR, e.g. chapter 7.2 on forestry and chapter 16 on the inventory of Greenland.

To a large extent many of the QC checks are done automatically in databases or spreadsheets were outliers are flagged for follow-up. This is done both in terms of emission trends and emission recalculations. Work is ongoing to automate the IEF time series and to automatically flag large inter-annual fluctuations.

8 Quality assurance procedures

The objective of QA procedures is to ensure an independent qualified review to assess the quality of the inventory and to provide suggestions for further improvements.

The QA procedures for the Danish greenhouse gas inventory can be separated in two main activities: international reviews of the whole inventory and reviews of the single sectors or subsectors of the inventory.

The Danish greenhouse gas inventory is reviewed annually by an expert review team composed of experts nominated by Parties to the UNFCCC Roster of Experts.

8.1 International reviews of the Danish inventory

The Danish greenhouse gas inventory is annually subjected to several different types of review under the European Union (EU) and the UNFCCC.

8.1.1 UNFCCC reviews

The key element is the UNFCCC/KP reviews consisting of an initial check, synthesis and assessment report (SAR) and finally an in-depth review. While the initial checks are an aggregated overview of completeness, both the SAR and the in-depth review are providing valuable checks regarding the transparency, accuracy, completeness, comparability and consistency.

The outcome of the UNFCCC review process is published annually in reports available from the UNFCCC website: http://unfccc.int/national_reports/annex_i_ghg_inventories/inventory_review_reports/items/6048.php

All reports dating back to the first UNFCCC review can be found on the website. As of 2012, Denmark has been reviewed 11 times under the UNFCCC process. The first review took place as a desk review in 2001. Since then Denmark has had eight centralized reviews and two in-country reviews.

The recommendations made by the expert review team are tracked by the Danish inventory team and the progress is reported annually in chapter 10 of the National Inventory Report (NIR), see e.g. Nielsen et al. (2019). This process ensures that all recommendations are registered and it is documented what actions have been undertaken to resolve the issue identified by the UNFCCC Expert Review Team (ERT).

In general, it is sought to address all issues identified by the ERT during the following annual submission. However, due to the timing of the reviews and the late availability in some years of the draft review report, it is sometimes not possible. In these cases, the issues are tracked in the NIR and implemented in the following submission.

8.1.2 EU reviews

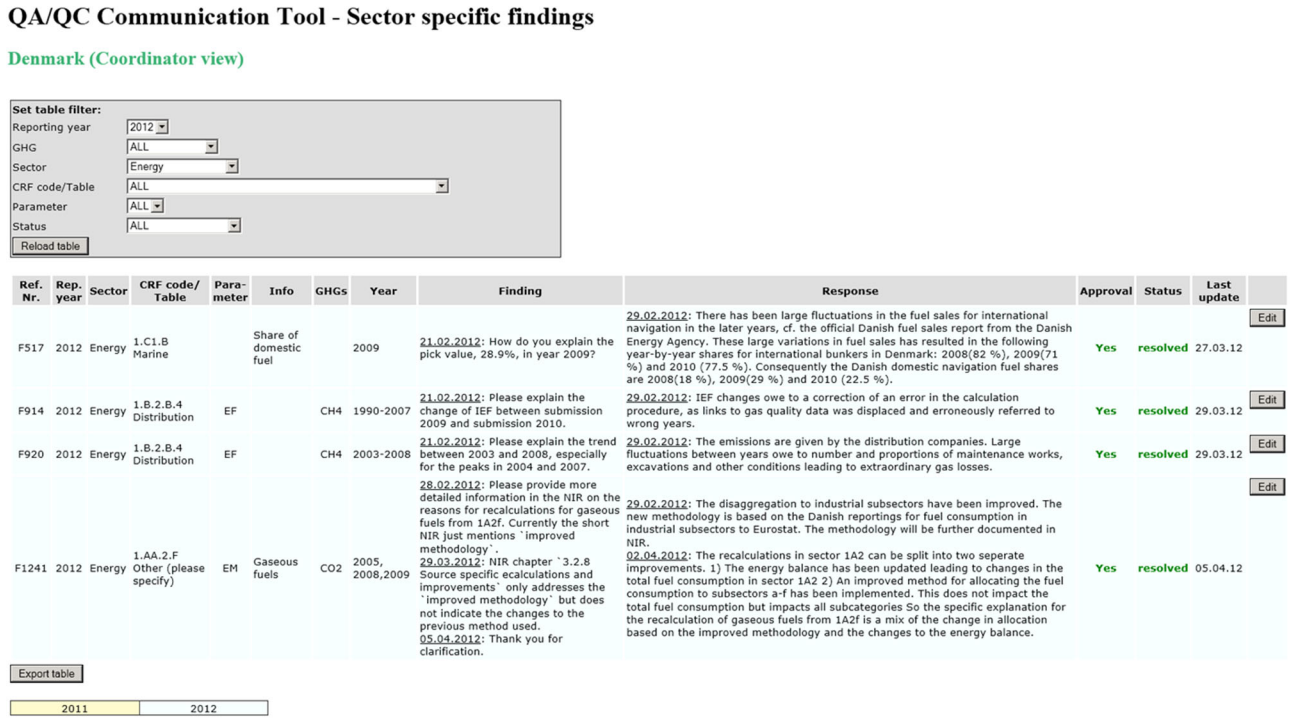
The internal quality control of Member States (MS) reporting serves as a QA of the Danish greenhouse gas emission inventory. Denmark is obligated to annually report a full emission inventory to the EU by 15 January.

Annual reviews

As part of the annual reporting cycle, Denmark receives detailed comments from EU experts related to our 15 January submission. The comments are received by 28 February. This provides Denmark with the opportunity to address the identified issues either in the CRF or the NIR before the final submission deadline to the UNFCCC on 15 April.

The checks carried out by the EU addresses all the quality parameters as included in the IPCC Guidelines (TACCC – Transparency, Accuracy, Completeness, Consistency and Comparability). An example of the structure and nature of the questions are included in the screenshot of the online QA / QC communication tool, see Figure 4.

For the 2018 submission, the EU internal review identified 17 questions related to different aspects of the Danish greenhouse gas emission inventory. All the issues were addressed and resolved prior to the final reporting to the UNFCCC.



QA/QC Communication Tool - Sector specific findings

Denmark (Coordinator view)

Set table filter:

Reporting year: 2012
GHG: ALL
Sector: Energy
CRF code/Table: ALL
Parameter: ALL
Status: ALL
Reload table

Ref. Nr.	Rep. year	Sector	CRF code/ Table	Para-meter	Info	GHGs	Year	Finding	Response	Approval	Status	Last update	
F517	2012	Energy	1.C1.B Marine		Share of domestic fuel		2009	21.02.2012: How do you explain the pick value, 28.9%, in year 2009?	29.02.2012: There has been large fluctuations in the fuel sales for international navigation in the later years, cf. the official Danish fuel sales report from the Danish Energy Agency. These large variations in fuel sales has resulted in the following year-by-year shares for international bunkers in Denmark: 2008(82 %), 2009(71 %) and 2010 (77.5 %). Consequently the Danish domestic navigation fuel shares are 2008(18 %), 2009(29 %) and 2010 (22.5 %).	Yes	resolved	27.03.12	Edit
F914	2012	Energy	1.B.2.B.4 Distribution	EF		CH4	1990-2007	21.02.2012: Please explain the change of IEF between submission 2009 and submission 2010.	29.02.2012: IEF changes owe to a correction of an error in the calculation procedure, as links to gas quality data was displaced and erroneously referred to wrong years.	Yes	resolved	29.03.12	Edit
F920	2012	Energy	1.B.2.B.4 Distribution	EF		CH4	2003-2008	21.02.2012: Please explain the trend between 2003 and 2008, especially for the peaks in 2004 and 2007.	29.02.2012: The emissions are given by the distribution companies. Large fluctuations between years owe to number and proportions of maintenance works, excavations and other conditions leading to extraordinary gas losses.	Yes	resolved	29.03.12	Edit
F1241	2012	Energy	1.AA.2.F Other (please specify)	EM	Gaseous fuels	CO2	2005, 2008,2009	28.02.2012: Please provide more detailed information in the NIR on the reasons for recalculations for gaseous fuels from 1A2f. Currently the short NIR just mentions `improved methodology`. 29.03.2012: NIR chapter `3.2.8 Source specific ecalculations and improvements` only addresses the `improved methodology` but does not indicate the changes to the previous method used. 05.04.2012: Thank you for clarification.	29.02.2012: The disaggregation to industrial subsectors have been improved. The new methodology is based on the Danish reportings for fuel consumption in industrial subsectors to Eurostat. The methodology will be further documented in NIR. 02.04.2012: The recalculations in sector 1A2 can be split into two seperate improvements. 1) The energy balance has been updated leading to changes in the total fuel consumption in sector 1A2 2) An improved method for allocating the fuel consumption to subsectors a-f has been implemented. This does not impact the total fuel consumption but impacts all subcategories So the specific explanation for the recalculation of gaseous fuels from 1A2f is a mix of the change in allocation based on the improved methodology and the changes to the energy balance.	Yes	resolved	05.04.12	Edit

Export table

2011 | 2012

Figure 4 Example of QA procedure carried out by EU experts.

Other activities

In 2012, 2016 and 2020, separate in-depth reviews was carried out for all EU MS as part of the implementation of the Effort Sharing Decision (ESD) and Effort Sharing Regulation (ESR). The in-depth review consisted of a desk review of all MS inventories followed by a centralised review. During these very comprehensive reviews, additional questions were raised and this led to further improvements of the Danish greenhouse gas inventory.

8.2 National QA activities

As a very important part of the QA activities methodological reports are prepared for each sector / subsector. These reports are subsequently peer reviewed by either a national or an international expert within the field that has not been involved in the preparation of the Danish emission inventory.

This practice has been occurring in Denmark for several years in particular for the most important source sectors, i.e. stationary and mobile combustion. Table 4 provides an overview of the sectoral reports prepared to date and the plan for elaborating sectoral reports in future years.

Table 4 List of completed and planned sectoral reports.

Sector	Previous versions	Most recent version	Next version
Stationary combustion	2003, 2004, 2006, 2007, 2009, 2010, 2014	2018[1]	2020
Mobile combustion	2004, 2007, 2008, 2012, 2015	2018[2]	2020
Fugitive emissions from fuels	2009	2015[3]	2020
Industrial processes and product use	2010, 2014, 2015	2018[4]	2022
Agriculture	2006, 2011, 2014	2017[5]	2020
LULUCF			2020
Solid waste disposal on land		-	2020
Wastewater handling	2005	2016[6]	2021
Other waste treatment		2013[7]	Not scheduled

[1] Nielsen et al., 2018; [2] Winther, 2018; [3] Plejdrup et al., 2015; [4] Hjelgaard et al., 2018; [5] Albrektsen et al., 2017; [6] Thomsen, 2016, [7]Hjelgaard, 2013.

In general, it is the plan to have sectoral reports updated and reviewed at least every three years. However, there are other considerations that can affect the schedule, e.g. major changes in methodology will prompt the need for an updated sectoral report. On the other hand, if no methodological changes have occurred, it is not a necessity to update the sectoral report.

The task of finding suitable reviewers is challenging. The review of a sectoral report is a big task that requires substantial time available. Also, it is necessary to find experts with the knowledge to evaluate the methodologies used in the inventory and to contribute with constructive criticism of the choices made by the inventory compilers.

In some cases, it is not possible to find a reviewer suited to review all aspects of the sectoral report, e.g. for mobile combustion activities vary from aviation to road transport and different non-road machinery. In these cases, different approaches have been used. In some cases the report has been reviewed by more than one reviewer, in other cases where only one reviewer has been used, it is ensured that the subsequent version of the sectoral report is reviewed by an expert with a different area of expertise. This ensures that all aspects of the given sector are reviewed in time.

The reviewers that have contributed to the QA by performing peer review of the sectoral reports are listed in Table 5 below with their affiliation at the time. They have all contributed with valuable input that has led to improvements in the emission inventory related to both accuracy and transparency.

Table 5 Reviewers contributing to QA of Danish sectoral reports.

Sector	Reviewer(s)	Affiliation
Stationary combustion	Bo Sander	Elsam
	Jan Erik Johnson	Technical University of Denmark
	Annemette Geertinger	Force Technology
	Vibeke Vestergaard Nielsen	DCE - Danish Centre for Environment and Energy, Aarhus University
	Experts from the Danish Energy Agency	Danish Energy Agency
Mobile combustion	Spencer Sorenson	Technical University of Denmark
	Kaj Jørgensen	Risoe National Laboratory
	Erik Iversen	Danish Environmental Protection Agency
	Hans Otto H. Kristensen	Technical University of Denmark
	Jens-Erik Ditlevsen	Danish Transport Authority
Fugitive emissions from fuels	Anette Holst	Statoil A/S, The Refinery, Denmark
Industrial processes	Jytte Boll Illerup	Danish Environmental Agency
	Vibeke Vestergaard Nielsen	DCE - Danish Centre for Environment and Energy, Aarhus University
Solvent and other product use	Nina Holmengen,	Statistics Norway
Agriculture	Peter Lund	Aarhus University, Department of Animal Science
	Rolf Adolpsson	Statistics Sweden
	Nick Hutchings	Aarhus University, Department of Agroecology
	Johnny M. Andersen	University of Copenhagen
Wastewater handling	Niels Iversen	Aalborg University
	Mette W. Pedersen	Danish Environmental Protection Agency
	Riitta Piipati	Statistics Finland
	Hans Oonk	OonKAY!

All the response received from the reviewers during the QA process is incorporated in the annual inventory submission and documented both in the NIR and in the subsequent sectoral report.

Another QA activity carried out on parts of the Danish inventory is the publication of papers in peer-reviewed journals documenting the country-specific methodologies developed for certain subsectors. These include country-specific methodologies for non-road machinery (Winther & Nielsen, 2007), navigation (Winther, 2008), Danish emission inventory for solvents used in industries and households (Fauser & Illerup, 2008) and uncertainty calculations (Fauser et al., 2011).

9 Relationship between the Danish QA/QC plan and UNFCCC and IPCC definitions and requirements

The requirements to perform and report on QA / QC activities are included in UNFCCC reporting guidelines (UNFCCC, 2014) as well as in decisions under the Kyoto Protocol (e.g. decision 19 / CMP.1). The technical guidance to Parties on how to address QA / QC is provided by the IPCC in the 2006 IPCC Guidelines (IPCC, 2006).

9.1 UNFCCC and KP requirements

The requirements associated with reporting of QA / QC procedures under the convention are included in the UNFCCC reporting guidelines (UNFCCC, 2014). According to the reporting guidelines (§ 17), it is mandatory for each Party to elaborate a QA / QC plan and implement general inventory QC procedures. In addition, it is encouraged that category-specific QC procedures are implemented for key categories and for those individual categories in which significant methodological changes and / or data revisions have occurred. Also, it is encouraged that Parties implement QA procedures by conducting a basic expert peer review of their inventories.

These requirements are also included in decision 19 / CMP.1 (UNFCCC, 2005) specifying the requirements for National Systems under the Kyoto Protocol. An overview of the mandatory and non-mandatory requirements of decision 19 / CMP.1 is provided in Table 6.

Table 6 UNFCCC requirements for QA/QC of the greenhouse gas inventory.

Element	Paragraph	Legal text	Status
QA/QC plan	12(d)	Elaborate an inventory QA/QC plan, which describes specific QC procedures to be implemented during the inventory development process, facilitate the overall QA procedures to be conducted, to the extent possible, on the entire inventory and establish quality objectives.	Mandatory
Basic QC	14 (g)	Implement general inventory QC procedures (tier 1) in accordance with its QA/QC plan following the IPCC Guidelines.	Mandatory
Source specific QC	15 (a)	Apply source-category-specific QC procedures (tier 2) for key source categories and for those individual source categories in which significant methodological and/or data revisions have occurred, in accordance with the IPCC Guidelines.	Non-mandatory
Basic QA	15 (b)	Provide for a basic review of the inventory by personnel that have not been involved in the inventory development, preferably an independent third party, before the submission of the inventory, in accordance with the planned QA procedures referred to in paragraph 12 (d) above.	Non-mandatory
Source specific QA	15 (c)	Provide for a more extensive review of the inventory for key source categories, as well as source categories where significant changes in methods or data have been made.	Non-mandatory
QA follow-up	15 (d)	Based on the reviews described in paragraph 15 (b) and (c) above and periodic internal evaluations of the inventory preparation process, re-evaluate the inventory planning process in order to meet the established quality objectives referred to in paragraph 12 (d).	Non-mandatory
Archiving of QA/QC information	16 (a)	Archive inventory information for each year in accordance with relevant decisions of the COP and/or COP/MOP. This information shall also include internal documentation on QA/QC procedures, external and internal reviews, documentation on annual key sources and key source identification and planned inventory improvements.	Mandatory

The QA / QC plan as required is documented in this report. As mentioned this plan is periodically updated but since the QA / QC system is operating, it is not necessary to update the plan with high frequency. The results of the specific QA / QC activities are reported annually in the NIR.

All the QC requirements, both mandatory and non-mandatory, are covered by the PMs described in Chapter 6. The basic QC activities (tier 1) are carried out mostly as general PMs across all sectors. The source-specific QC activities (tier 2) are carried out at sectoral or subsectoral level and reported accordingly in the NIR.

All QA activities are non-mandatory. However, this is a vital component to ensure the ongoing improvement. The QA processes are described in Chapter 8 and the results of the QA are reported annually in the NIR.

The documentation of the QA / QC procedures is archived as part of the general archiving system put in place as part of the mandatory requirements of the Danish National System. The majority of the documentation is included in the NIR on an annual basis to ensure the highest degree of transparency regarding the QA / QC procedures for the Danish greenhouse gas emission inventory.

9.2 IPCC guidance

The current IPCC guidance for performing QA and QC activities are included in the 2006 IPCC Guidelines (IPCC, 2006).

9.2.1 Tier 1 QC

As part of the general QC procedures, the IPCC Guidelines recommends a number of standardised checks. These are included in

Table 7.

Table 7 IPCC recommended tier 1 QC procedures and the connection to PMs in the Danish QC manual.

QC Activity	Procedures	Related PMs	Comments
Check that assumptions and criteria for the selection of activity data and emission factors are documented.	Cross-check descriptions of activity data and emission factors with information on source categories and ensure that these are properly recorded and archived.	DS.1.3.1 DS.1.4.1 DS.1.7.1	
Check for transcription errors in data input and reference.	Confirm that bibliographical data references are properly cited in the internal documentation. Cross-check a sample of input data from each source category (either measurements or parameters used in calculations) for transcription errors.	DS.1.4.1 DP.1.7.2 DS.2.7.1	
Check that emissions are calculated correctly.	Reproduce a representative sample of emissions calculations. Selectively mimic complex model calculations with abbreviated calculations to judge relative accuracy.	DS.1.5.2 DS.1.5.3 DS.2.5.1 DS.3.5.1 DS.3.5.2 DS.3.5.3	
Check that parameter and emission units are correctly recorded and that appropriate conversion factors are used.	Check that units are properly labelled in calculation sheets. Check that units are correctly carried through from beginning to end of calculations. Check that conversion factors are correct. Check that temporal and spatial adjustment factors are used correctly.	DS.2.5.1 DS.3.5.1 DS.3.5.2 DS.3.5.3	Very similar to the checks performed in the row above. No temporal or spatial adjustment is done, so this is not relevant.
Check the integrity of database files.	Confirm that the appropriate data processing steps are correctly represented in the database. Confirm that data relationships are correctly represented in the database. Ensure that data fields are properly labelled and have the correct design specifications. Ensure that adequate documentation of database and model structure and operation are archived.	DS.3.7.1 DS.3.7.2 DP.3.7.1 DP.3.7.2	
Check for consistency in data between source categories.	Identify parameters (e.g. activity data, constants) that are common to multiple source categories and confirm that there is consistency in the values used for these parameters in the emissions calculations.	DP.1.4.2	
Check that the movement of inventory data among processing steps is correct.	Check that emissions data are correctly aggregated from lower reporting levels to higher reporting levels when preparing summaries. Check that emissions data are correctly transcribed between different intermediate products.	DS.2.5.1 DS.4.5.1	
Check that uncertainties in emissions and removals are estimated or calculated correctly.	Check that qualifications of individuals providing expert judgement for uncertainty estimates are appropriate. Check that qualifications, assumptions and expert judgements are recorded. Check that calculated uncertainties are complete and calculated correctly. If necessary, duplicate error calculations or a small sample of the probability distributions used by Monte Carlo analyses.	DS.1.1.1 DP.1.1.1 DP.2.1.1 DP.2.7.2 DS.3.1.1	
Undertake review of internal documentation.	Check that there is detailed internal documentation to support the estimates and enable duplication of the emission and uncertainty estimates. Check that inventory data, supporting data, and inventory records are archived and stored to facilitate detailed review. Check integrity of any data archiving arrangements of outside organisations involved in inventory preparation.	DS.1.7.1 DS.1.7.2 DP.1.4.1 DP.1.7.1 DP.2.7.1	

QC Activity	Procedures	Related PMs	Comments
Continued			
Check methodological and data changes resulting in recalculations.	Check for temporal consistency in time series input data for each source category. Check for consistency in the algorithm/method used for calculations throughout the time series.	DP.1.4.1 DS.2.7.1 DS.3.5.3 DS.4.4.2	
Undertake completeness checks.	Confirm that estimates are reported for all source categories and for all years from the appropriate base year to the period of the current inventory. Check that known data gaps that result in incomplete source category emissions estimates are documented.	DP.1.3.1 DS.4.3.1 DS.4.3.2	
Compare estimates to previous estimates.	For each source category, current inventory estimates should be compared to previous estimates. If there are significant changes or departures from expected trends, recheck estimates and explain any difference.	DS.3.5.1	

All the general QC checks recommended in the IPCC Guidelines have been considered in the Danish inventory as PMs and are therefore fully addressed.

9.2.2 Tier 2 QC

The IPCC Guidelines considers source-specific QC as tier 2 in contrast to the general QC checks described in Chapter 9.2.1.

The IPCC Guidelines considers three specific activities at the tier 2 level:

- Emission data QC
- Activity data QC
- QC of uncertainty estimates

The first bullet refers to QC checks of IPCC default emission factors, country-specific emission factors and plant-specific / measured emission factors.

The applicability of the chosen emission factors and comparison to international values including IPCC default emission factors are included in PM DS.1.2.1 and documented in the NIR. For country-specific emission factors these are checked against the IPCC defaults. Furthermore, if the country-specific emission factors are based on secondary sources, the quality is assessed analysing the underlying measurements. Only emission factors based on measurements carried out and analysed by accredited organisations are used in the Danish inventory. Also country-specific emission factors are compared to plant-specific emission factors where available. The results of these checks are documented in the NIR.

To the extent they are available, plant-specific emission factors are used in the Danish inventory. When using plant-specific data these are based on strict monitoring guidelines (e.g. under the EU ETS). However, even in these cases DCE conducts QC checks to ensure the applicability of the derived emission factors.

Further tier 2 QC checks includes emission comparisons, e.g. where the emission result is compared to previous estimates (PM DS.3.5.1) or where the trend is analysed and any outliers are identified and checked (PM DS.3.5.3). These checks are carried out at detailed source category level with priority given to key categories.

Regarding the use of activity data, the Danish inventory is based on official statistics (e.g. from the Danish Energy Agency, Statistics Denmark, the Danish Environmental Protection Agency, the Danish Plant Directorate, etc.) and from specific sites / companies. When using the official statistics, DCE is considering that these are of good quality and the responsible organisations have own QC systems in place. However, DCE performs general (tier 1) QC checks on the data in particular with respect to recalculation and / or dips and jumps in the time series.

For site-specific data, DCE also performs general QC checks in comparing the values with those of pervious years to identify possible errors. When multiple data sources are available the data is cross-checked between the different data sources and any discrepancies are resolved by contact to the company in question.

The QC of the uncertainty estimates is carried out both in respect to the evaluation of the uncertainty assigned to the activity data and emission factors but also to the methodology for estimating the total uncertainty and the uncertainty of the trend. These issues are covered by several PMs on different levels of data handling (PMs DS.1.1.1, DP.1.1.1, DP.2.1.1, DS.3.1.1).

9.2.3 QA procedures

The 2006 IPCC Guidelines provides limited information on QA procedures. It distinguishes between expert peer-review and audits.

According to the 2006 IPCC Guidelines the peer-review can be conducted either for the inventory as a whole or in smaller parts. Furthermore, it is considered good practice to involve reviewers that have not been directly involved in the inventory preparation and that these experts preferably should be independent experts from other agencies or a national or international expert or group not closely connected with national inventory compilation.

It is stated that prioritisation should be given to key categories and for any categories where significant methodological changes have occurred.

The Danish QA plan follows closely the guidance by the IPCC. Expert reviews are carried out both for the inventory as a whole (UNFCCC and EU reviews) and for specific source categories. In accordance with the guidance, priority is given to the largest categories in term of emissions, and hence the sectors with most frequent expert peer-review have been stationary combustion, mobile combustion and agriculture. These three categories account for nearly 95 % of the Danish greenhouse gas emissions.

Denmark has chosen to prioritise expert peer-review rather than audits. The area of greenhouse gas inventories and the complex models and underlying methodologies makes it necessary with a high degree of technical competence rather than the more simple approach of a traditional bookkeeping audit.

More information on the QA procedures for the Danish greenhouse gas emission inventory is provided in Chapter 8.

9.2.4 Verification

The IPCC Guidelines (IPCC, 2006) provides limited guidance concerning verification procedures.

The 2006 IPCC Guidelines states that comparison of emission inventory data with other independently compiled, national emissions data are an option to evaluate completeness, approximate emission levels and correct source category allocations. Furthermore, it is mentioned that the comparisons can be made for different greenhouse gases at national, sectoral, source category, and sub-source category levels.

According to the IPCC Guidelines, the verification techniques include internal quality checks, inventory inter-comparison, comparison of intensity indicators, comparison with atmospheric concentrations and source measurements, and modelling studies.

Specifically, the following activities are described:

- Comparisons with other national emissions data
- Comparison with national scientific and other publications
- Bottom-up, top-down comparisons
- Comparisons of national emission inventories with independently compiled, international datasets
- Comparisons of activity data with independently compiled datasets
- Comparisons of emission factors between countries
- Comparisons based on estimated uncertainties
- Comparisons of emission intensity indicators between countries
- Comparisons with atmospheric measurements at local, regional and global scales
- Comparisons with international scientific publications, global or regional budgets and source trends

These activities are of varying usefulness and consequently not all of these activities have been implemented as part of the QA/QC work on the Danish greenhouse gas inventory. More information on the verification activities undertaken by the Danish inventory team is included in Chapter 10.

10 Verification procedures

The verification process can help evaluate the uncertainty in emissions estimates, taking into account the quality and context of both the original inventory data and data used for verification purposes.

For many of the verification processes described in the 2006 IPCC Guidelines, it is difficult to find suitable independent data. In many cases the alternative datasets are not completely independent since they to some extent are based on the same raw data. Nevertheless, these checks can be used to some degree to assess the completeness and the correctness of the emission inventory.

10.1 Comparisons with other national emissions data

There are very limited options for making comparisons with other national data. There are no regional emission inventories that can be used. All national statistical data have been used in the process of inventory preparation and there is therefore no possibility to compare with independent national emission estimates.

For large point sources, there is in theory a possibility for verifying greenhouse gas emissions. Large point sources are obligated to report emissions under the European Union Emission Trading Scheme (EU ETS) and the European Union E-PRTR (Electronic Pollutant Release and Transfer Registry) Directive. However, the Danish inventory directly utilises the data reported under the EU ETS if the plants have based the reporting on plant/fuel specific measurements. For the remaining plants, the Danish country-specific emission factors developed as part of the greenhouse gas inventory are used and hence there is no verification of the inventory in performing this comparison. Comparisons are made but mostly to identify erroneous reporting under the EU ETS.

Similarly, the data reported under the E-PRTR are of no use for verification. For CO_2 the data are either identical to the EU ETS data or are based on the emission factors used in the Danish greenhouse gas inventory. For the other greenhouse gases the E-PRTR data are almost exclusively based on the emission factors published by DCE annually as part of the emission inventory work. Therefore, the comparisons usually serve to identify errors in the E-PRTR reporting and not as a verification of the Danish greenhouse gas inventory.

10.2 Comparison with national scientific and other publications

DCE continuously monitor the publication of relevant information by other Danish institutions. This includes e.g. the publication of research papers and dissertations from Danish universities and research institutions. Also technical reports elaborated for e.g. the Danish Energy Agency or the Danish Environmental Protection Agency are examined for any knowledge that can be used to verify or improve the Danish greenhouse gas emission inventory.

10.3 Bottom-up, top-down comparisons

Some checks of this nature are done annually as part of the mandatory reporting requirements. This is for instance the case for the comparison between the reference and sectoral approaches for CO_2 emissions from fuel combustion. The result of the check is reported annually in the NIR and any major differences are investigated and explained.

Another check is done for road transport where the fuel consumption is calculated bottom-up annually based on a complex model taking into account vehicle stock data, mileage data and trip speeds. The bottom-up estimated fuel consumption is compared to the registered fuel sale as included in the official Danish energy statistics. The result of the comparison is reported annually in the NIR.

The emission of CO_2 from brickworks was initially based on assumptions on average weight of bricks and average content of calcium carbonate ($CaCO_3$) in yellow bricks. This model was verified by comparison with EU-ETS data for 1998-2002, and a good agreement between the initial estimations and EU-ETS was seen.

The majority of emissions from the agricultural sector depend on livestock production and nitrogen excretion can be used as an indicator of the scale of this production. The emission inventory is calculated using the N excretion on the basis of a comprehensive model that takes into account the categories of livestock, housing types and manure type. This bottom-up assessment should be compared with data from the Danish Centre for Food and Agriculture (DCA), which is responsible for the normative data. It is planned to investigate whether such data can be obtained from DCA.

10.4 Comparisons of national emission inventories with independently compiled, international datasets

There are available global databases of emissions. Examples are the CO_2 emissions estimates from combustion of fossil fuels that are compiled by the International Energy Agency (IEA) and the Carbon Dioxide Information and Analysis Centre (CDIAC).

Global total anthropogenic inventories of all greenhouse gases are compiled by the Global Emission Inventory Activity (GEIA) and the Emission Database for Global Atmospheric Research (EDGAR).

Potentially, these comparisons can assist in checking completeness, consistency, source allocation and accuracy to within an order of magnitude. However, it must be noted that the data sources are not independent, e.g. the official Danish energy statistics are used in the greenhouse gas emission inventory and are also the basis of the Danish reporting to the IEA, which is the basis for the emission estimates made by IEA and EDGAR.

As a consequence of this weakness this area has not been prioritized for the Danish verification activities. There are currently no plans to implement a check of the Danish emission inventory with the international emission estimates prepared by GEIA or EDGAR.

10.5 Comparisons of activity data with independently compiled datasets

Similarly to the checks for emissions described in Chapter 10.4, checks can also be made concerning activity data, e.g. between IEA data for fuel consumption or FAO data for number of livestock. In the Danish case, checks can also be made using data published by Eurostat that is the statistical office of the European Union. Again, there should not be any large differences as the activity data used in the Danish inventory are based on the official statistics also reported to international organisations, e.g. IEA, FAO and Eurostat.

The energy data reported by Denmark in the CRF tables are annually compared to the IEA data as part of the standardised checks done by the UNFCCC during part II of the synthesis and assessment report. The discrepancies are usually very low (1-2 %). Much of the difference can be attributed to the differences in geographical coverage. The IEA reporting includes mainland Denmark only while the CRF under the UNFCCC also consists of Greenland and the Faroe Islands (Under the Kyoto Protocol the Faroe Islands are not included).

FAO data have been used as verification of the activity data used for calculating emissions from the agricultural sector in Denmark from 2012.

10.6 Comparisons of emission factors between countries

This activity covers three main aspects: direct comparison of applied emission factors, comparison of implied emission factors (IEFs) and comparison with IPCC default values.

In the Danish inventory, it has mostly been a comparison with IPCC default values that have been used for verification. For stationary combustion the CO_2 emission factors have been compared to the IPCC default values and results have been reported in the NIR in the chapter discussing the choice of emission factors.

For agriculture a comparison has been made for enteric fermentation for cattle between the IPCC tier 2 methodology and the country-specific methodology used in the Danish inventory. The result of the comparison is reported in the NIR.

Comparing emission factors directly is difficult due to few countries reporting the applied emission factors. Therefore, the most feasible verification is to compare IEFs from the CRF reporting made by countries to the UNFCCC. In the future it will be considered to include comparison of IEFs for key categories between countries as part of the verification of the Danish inventory.

10.7 Comparisons based on estimated uncertainties

The work of collecting the uncertainties associated with specific emission factors for other countries has been deemed to excessive compared to the possible benefits. Therefore, this type of comparison is not considered to be feasible for implementation in the Danish quality work.

10.8 Comparisons of emission intensity indicators between countries

The most extensive verification work of the Danish greenhouse gas inventory was done by comparing emission density indicators between countries in 2007 (Fauser et al., 2007). The report compared multiple indicators for different source sectors for several countries considered to be comparable to Denmark. The focus was on key categories covering stationary combustion, mobile combustion, industrial processes, agriculture and waste. The study covered CO_2 from fuel combustion and industrial processes, methane (CH_4) and nitrous oxide (N_2O) from agriculture and CH_4 from waste).

The used verification procedure was appropriate for evaluating data consistency and reliability for the energy sector. For agriculture, industrial processes and waste the implied emission factors were not reported, which impeded parts of the suggested verification procedure. For all sectors the method gave good possibility for checking consistency in time trends.

A new verification study (Fauser et al., 2013) was carried out to update and complement the first version. The new verification study is more extensive covering 28 key categories across sectors, excluding LULUCF. It consists of five different levels of verification for 1990, 2000 and 2010 GHG emissions:

- Inter-country comparison of Annex II Priority indicators, Additional indicators and Supplementary indicators, for the energy and industry sector
- Inter-country comparison of reported IEFs
- Inter-country verification of reported activity data and independent energy use, agricultural and waste data from OECD and FAOstat
- National verification of energy sector (reference method)
- National verification/comparison with independent data for agriculture and waste.

The aim of the process is to obtain valid comparison of key indicators between Denmark and other countries and to perform verification of EFs and activity data with independent data. The results are used to assess the completeness, comparability and accuracy of the Danish greenhouse gas inventory.

Due to the large work associated with collecting and processing the data needed for the verification, it is not feasible to conduct this type of study annually or even biennially. As part of the QA/QC plan for the Danish greenhouse gas inventory, it is planned to update the verification study every five years.

10.9 Comparisons with atmospheric measurements at local, regional and global scales

The IPCC Guidelines mentions several options that can be used in comparing emission inventories with atmospheric measurements. These include: local and regional atmospheric sampling, continental plumes, satellite observations and global dynamic approaches.

Most of these options are more suited for regional or global verification than national verification, in particular for a small country like Denmark. Both continental plumes and global dynamic approaches are not applicable for Denmark. The use of satellite monitoring to estimate emissions is not feasible due

to the cost of such verification and also the high uncertainty associated with such estimates.

The use of inverse modelling to estimate emissions based on atmospheric measurements is the option that could yield some results. A previous study (Manning, 2007) has compared official reporting to the UNFCCC with the emission results of inverse modelling. The comparison was made for the United Kingdom and for northwest Europe. In general, the officially reported figures in most cases were within the uncertainty of the estimate derived by inverse modelling.

There are no plans of using inverse modelling as a means of verification of the Danish greenhouse gas inventory.

10.10 Comparisons with international scientific publications, global or regional budgets and source trends

No comparisons have been made with global or regional emission budgets. Furthermore, it is not believed that any such activities could contribute to the verification and/or improvement of the Danish Greenhouse gas inventory. Therefore, there are no plans to undertake such activities.

11 Future plans for the quality work

The Danish inventory team will continue to evaluate the QA/QC plan and this quality manual to ensure that it is kept up-to-date and it is modified to take into account any changes in requirements as well as the input received during the peer review of the inventory. In the coming years efforts will be made to strengthen the national QA processes by preparing more sectoral reports and for some sectors also with an increased frequency compared to what has historically been achieved. The QC procedures will continuously be updated to reflect the lessons learned during the review process. Any errors that have not been identified in the internal QC but are brought to our attention by outside sources will be evaluated thoroughly to establish whether the error is related to a shortcoming in the QC procedures or it is a problem with the implementation of the current QC procedures.

The next version of this report will be prepared in connection with implementation of the reporting under the Paris Agreement. This entails that the updated version will be published in 2024/2025.

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QUALITY MANUAL FOR THE DANISH GREENHOUSE GAS INVENTORY

Version 3

This report outlines the quality work undertaken by the emission inventory group at the Department of Environmental Science, Aarhus University in connection with the preparation and reporting of the Danish greenhouse gas inventory. This report updates and expands on the first versions of the quality manual published in 2005 and 2013. The report fulfils the mandatory requirements for a quality assurance/quality control (QA/QC) plan as lined out in the UNFCCC reporting guidelines and the specifications related to reporting under the Kyoto Protocol. The report describes all elements of the internal QC procedures as well as the QA and verification activities carried out in connection with the Danish greenhouse gas inventory.

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